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THE UNITED STATES
STRATEGIC BOMBING SURVEY

JAPANESE AIR WEAPONS AND TACTICS

REGRADED UNCLASSIFIED
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Military Analysis Division

January 1947

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THE UNITED STATES STRATEGIC BOMBING SURVEY

CORRECTIONS TO PACIFIC WAR REPORT NO. 63, JAPANESE AIR WEAPONS AND TACTICS

(*1 June 1947*)

Correction	*Page*	*Column*	
1	VI	2	Item 20 b, line 3, and item 20 d, line 2, "USSBA" should read "USSBS."
2	3	2	Line 21 should read "existing mounts".
3	6	1	Under "JAAF Purchases," lines 8, 10, 11, and 12, "Mg" should read "MG."
4	--	2	Lines 13, 15, and 16, "Mg" should read "MG." Lines 21, 23, 27, and 28, "Mk" should read "MK."
5	9	1	Line 21 should read, "Small model high-horsepowered."
6	15	1	Under "Joint Army-Navy Efforts (figure C)", line 17, "Japanese antiaircraft force" should read "Japanese Army Air Force."
7	17	1	Under "Shusui Development (figure C)", line 7, "Mk-103" should read "MK-108."
8	19	-	Under "Fuel consumption," "Light/hours" should read, "Liters/hour."
9	20	1	Under "Army Kamikaze Concept," line 13, make "Japanese Antiaircraft Force" read "Japanese Army Air Force."
10	22	2	Line 10, delete "(5)."
11	29	1	Line 23, "States Antiaircraft" should read, "States Army Air."
12	30	2	Line 13 under "B-29 Weakness," delete "c." at beginning of line.
13	32	1	Line 3, make "a long Jap" read "a lone Jap."
14	--	-	Lines 36 and 41, change "Mk" to "MK."

15. Page 33 should read as follows:

IX. MACHINE GUNS AND CANNON

General

The study of Japanese aircraft armament reveals a drastic failure on their part to standardize on any one particular weapon for each caliber size. The separate development projects carried out by the two services, army and navy, have produced an unsurpassed variety of weapons requiring various types of ammunition.

A parallel comparison of American and Japanese machine guns and ammunition types reveals the great extent of this failure to standardize (Fig. M & N).

FIGURE M.—*Aircraft machine guns—Operational types*

Caliber class	United States Air Forces: Army and Navy	Japanese Air Forces: Army or Navy
.30 inch	① cal. .30 Browning	① Cal. 7.7 millimeter type 89 Japanese A [1]. ② Cal. 7.7 millimeter type 89 Vickers A [2]. ③ Cal. 7.7 millimeter type 92 Lewis N [3]. ④ Cal. 7.7 millimeter type 97 Vickers N [2]. ⑤ Cal. 7.92 millimeter type 1 Dreyse-Solothurn MG15 N [4]. ⑥ Cal. 7.92 millimeter type 98 Dreyse-Solothurn MG15 A [4]. ⑦ Cal. 7.92 millimeter type 1 Bren A [5].
.50 inch	① cal. .50 Browning	① Cal. 12.7 millimeter HO 103 type 1 Browning A [6]. ② Cal. 13 millimeter type 2 Mauser MG-131 N [7]. ③ Cal. 13.2 millimeter type 3 Browning N [8].
20 millimeters	① cal. 20 millimeter Hispano-Suiza	① Cal. 20 millimeter HO-1 and 3 Japanese A [8]. ② Cal. 20 millimeter Mauser MG-151/20 A [9]. ③ Cal. 20 millimeter HO-5 Browning A [10].

⑧ Cal. 20 millimeter type 99 Oerlikon Mk-II N ⁱⁱ.
⑧ Cal. 20 millimeter type 99 Oerlikon Mk-II N ⁱⁱ.

DERIVATION OF BASIC DESIGNS

United States: Browning, Lewis. *Czech-British:* Bren. *German:* Mauser, Dreyse-Solothurn. *United States-British:* Vickers (Maxim). *Italian-Swiss.* Hispano-Suiza. *Swiss:* Oerlikon. A—Army. N—Navy.

Explanatory Notes: Aircraft Machine Guns (Figure M)

1. This weapon is a development of a light machine gun used by the ground forces. There were two distinct types: the single, fed by a flat drum magazine; and the dual, consisting of a right- and left-hand gun mounted on a light tubular frame and fed by two quadrant-shaped magazines.

2. The mechanism of these weapons is basically the same. However, though the calibers are both 7.7 millimeter, ammunition for one cannot be used in the other. The navy type 97 uses rimmed ammunition and the army type 89 was a semi-rimmed cartridge.

3. The navy 7.7 millimeter guns are chambered to fire the British .303 ammunition, and are almost exact copies of British models. Limited quantities of captured British ammunition were used.

4. Despite the identical caliber and common mechanism, no attempt was made to standardize these guns, and the components were not considered interchangeable.

5. This is a twin-mounted gun, and is sometimes designated the type 100.

6. These guns both bear a very close resemblance to the United States caliber .50 Browning, but none of the ammunition is interchangeable.

7. This gun is a very close copy of the German MG-131. The ammunition is similar to that used by the Germans, but, due to difficulty in perfecting the Luftwaffe's highly efficient electrical synchronization, the standard percussion type primer was employed.

8. The prototype of these guns was the Japanese Infantry 20 millimeter type 97 antitank rifle. Ammunition is the same for both types but the magazines are not interchangeable.

9. This weapon was imported in large quantities from Germany and has been found only with German-manufactured ammunition.

10. This gun is an enlarged model of the U. S.

Correction	*Page*	*Column*	
16	34	1	Line 6, add "11" at beginning of line.
17	--	-	Line 9, under "Development 1940–45," (German Mg–15) should read (German MG–15).
18	--	-	Line 16 under "Development 1940–45," should read, "Over Hankow."
19	--	2	Line 4, "Mk–108" should read "MK–108."
20	40	-	Bottom half, "NOTE JAP IN EFFICIENCY," should read, "NOTE JAP INEFFICIENCY."
21	42	2	Seventh line from bottom should read "believed that."
22	44	1	"a. General.—," remove "a."
23	--	2	Line 6, change "Antiaircraft" to "Army Air."
24	47	1	Line 16, change "a rocked-accelerated" to "a rocket-accelerated."
25	--	--	Line 2 under "Incendiary air-to-air bombs," should end "exclusively in."
26	--	2	Line 3, make "Mr–3" read "Mk–3."
27	--	-	Line 1 under "Cable Bombing (Figure AA)", change "antiaircraft" to "Army Air."
28	51	1	Line 5, make "Japananese" "Japanese."
29	--	2	Seventh line from bottom of page, make (3,281 feet) (3.2 feet).
30	53	1	Line 20 should read "Kanazawa,."
31	59	2	Fourth line from bottom should read (1,764 pounds).

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U. S. GOVERNMENT PRINTING OFFICE: 1947

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THE UNITED STATES
STRATEGIC BOMBING SURVEY

JAPANESE AIR WEAPONS AND TACTICS

Military Analysis Division

January 1947

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This report was written primarily for the use of the United States Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

FOREWORD

The United States Strategic Bombing Survey was established by the Secretary of War on 3 November 1944, pursuant to a directive from the late President Roosevelt. Its mission was to conduct an impartial and expert study of the effects of our aerial attack on Germany, to be used in connection with air attacks on Japan and to establish a basis for evaluating the importance and potentialities of air power as an instrument of military strategy for planning the future development of the United States armed forces and for determining future economic policies with respect to the national defense. A summary report and some 200 supporting reports containing the findings of the Survey in Germany have been published.

On 15 August 1945, President Truman requested that the Survey conduct a similar study of the effects of all types of air attack in the war against Japan, submitting reports in duplicate to the Secretary of War and to the Secretary of the Navy. The officers of the Survey during its Japanese phase were:

Franklin D'Olier, *Chairman*,
Paul H. Nitze, Henry C. Alexander, *Vice Chairmen.*
Harry L. Bowman,
J. Kenneth Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Fred Searls, Jr.,
Monroe E. Spaght,
Dr. Lewis R. Thompson,
Theodore P. Wright, *Directors.*
Walter Wilds, *Secretary.*

The Survey's complement provided for 300 civilians, 350 officers, and 500 enlisted men. The military segment of the organization was drawn from the Army to the extent of 60 percent, and from the Navy to the extent of 40 percent. Both the Army and the Navy gave the Survey all possible assistance in furnishing men, supplies, transport, and information. The Survey operated from headquarters established in Tokyo early in September 1945, with subheadquarters in Nagoya, Osaka, Hiroshima, and Nagasaki, and with mobile teams operating in other parts of Japan, the of the Pacific, and the Asiatic mainland.

It was possible to reconstruct much of wartime Japanese military planning and execution, engagement by engagement, and campaign by campaign, and to secure reasonable accurate statistics on Japan's economy and war production, plant by plant, and industry by industry. In addition, studies were conducted on Japan's over-all strategic plans and the background of her entry into the war, the internal discussions and negotiations leading to her acceptance of unconditional surrender, the course of health and morale among the civilian population, the effectiveness of the Japanese civilian defense organization, and the effects of the atomic bombs. Separate reports will be issued covering each phase of the study.

The Survey interrogated more than 700 Japanese military, government, and industrial officials. It also recovered and translated many documents which not only have been useful to the Survey, but also will furnish data valuable for other studies. Arrangements have been made to turn over the Survey's files to the Central Intelligence Group, through which they will be available for further examination and distribution.

Preface

The object of this report is to present a summary and unbiased analysis of all important phases of Japanese developments in air weapons and tactics. Special effort has been made to correlate recently acquired details with previous wartime observations. Obsolescent and current procedures, as well as pending developments are all included in order to present a more complete picture of Jap technical trends during the Greater East Asia War. Emphasis has been placed on those details which were unavailable prior to Japan's surrender.

This report is primarily based upon comprehensive inspections and interrogations covering civilian as well as Army and Navy phases. This included an examination of aircraft and weapons assigned to operational units; plus an inspection of aircraft plants, important manufacturing arsenals, and aeronautical research laboratories. Observations were supplemented by reports and interrogations of combat and test pilots, technicians, scientists, and officials. A few pertinent documents which survived the widespread prearmistice destruction program were also utilized in the preparation of this analysis.

Acknowledgment is made to the agencies enumerated in the bibliography for much of the basic data upon which this report is based.

These studies were initiated under the over-all direction of Maj. Gen. Orvil A. Anderson; with the executive assistance of Col. Robert H. Terrill and Col. Ramsay D. Potts.

This report, in both substance and final form, was prepared by the Air Weapons and Tactics Branch of the Military Analysis Division. The officers of this branch, who served with the Pacific Survey, were as follows:

Maj. John J. Driscoll, AC., chief, air weapons and tactics.

Capt. Robert E. Elsas, MI., statistical officer.

Lt. Benjamin Corey, AC., radar officer.

Lt. Richard L. Sneider, Inf., interpreter.

Lt. Hiromi Oyama, Inf., interpreter.

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I. JAPANESE TECHNOLOGY

For years the Japanese have been branded as "copyists." Did this trait contribute to the defeat of the nation? Do such procedures indicate a lack of initiative on the part of the Japanese engineer?

It is true that the Japanese technical establishments leaned to a great degree upon the corresponding fields in Europe and America. This practice, however, especially in the field of military science, is more or less universal, and the great saving in time, expense, and manpower warrants such action. An examination of weapons throughout history will show international use of the same basic designs. The famous U. S. Springfield M1903 rifle, manufactured and used extensively during both World Wars, was based on the design of the German Mauser. The highly efficient, though under-exploited, Butterfly Bomb was copied and recently manufactured, without deviation from the German model, by the U. S. Army Ordnance Department.

Despite their great reliance upon imitations and their lagging technical level, the Japanese must be given credit for individual initiative, as is frequently evidenced not only by original designs but by their practice of materially improving copies. In suicide weapons, for example, Japanese originality is plainly evident. Many weapons, including our own Browning machine gun, were improved by the Japanese before final adoption.

The vast gains accrued through copying were to a degree offset by the difficulties encountered in mass-producing highly specialized items. Satisfactory fabrication of the Norden bombsight, for example, was greatly impeded through inefficient Japanese mass-production methods.

Japan's technological level lagged behind that of the United States in much the same degree as the United States lagged behind Germany. The Nipponese lag was due to its late and incomplete industrial revolution which was hampered by the retention of many primitive methods in the less populated areas. The United States lag was primarily limited to the field of military weapons, and may be attributed to a prewar pacifist attitude which prohibited sufficient appropriations for education and research in armament engineering.

By far the most towering handicap to Japanese technical advance was the lack of standardization. Due to the insufficient coordination between the Army and Navy, and amplified by their low technical levels, the variety of equipment, from large aircraft to small instruments, was tremendous. As a consequence, the technicians, short as they were in quality and quantity, had to be used in weak, dispersed groups. This condition brought about the requirement of unnecessary efforts in many already overtaxed fields; design, production, modification, maintenance, supply, and even in training. The problems did not end here, but reacted continuously in combat by directly impeding operations. By tracing the development of the Browning machine gun from initial adoption to combat employment one may get an insight on the consequences of nonstandardization.

The Japanese Air Forces required a caliber .50 aircraft machine gun. Why not adopt the Browning which had already been fully tried and proven by both the Americans and British? The Japs not only adopted the gun, but incorporated some improvements in design, as well as increasing the rate of fire.[1] The Army and Navy each set their own staffs of designers on separate projects for this caliber .50 Browning machine gun. This was obviously duplicate effort, but there still remained the possibility of eventually combining ideas and production potentials. On the contrary, however, each service insisted on adhering to specific minor variations in design. The result was that each air force began manufacturing their own individual caliber .50 machine gun; both Browning actions, but not quite identical enough to allow interchangeability of either assemblies of separate

[1] Later, despite long-established opinions of American arms experts to the effect that the caliber .50 was the maximum possible size for the Browning type mechanism, Jap initiative produced and used operationally a Browning 20 millimeter machine gun and had completed an experimental 37 millimeter model.

components. This condition was further aggravated by each air arm adopting a different cartridge design; two cartridges in the same category, but the Navy adopted a caliber .51 cartridge in opposition to the Army's caliber .50.

Commander Kofukuda cites an instance in his combat experiences when his squadron had to stand down operations because the machine gun ammunition on a well-stocked adjacent Army air base would not fit the chamber of their similar type guns. The story of the caliber .50 Browning is not an isolated case, but is typical of Japan's self-imposed handicaps resulting from poor cooperation.

II. ARMY-NAVY COOPERATION

General

Throughout the war, numerous efforts were extended to amplify cooperation between the Army and Navy. It became increasingly evident that many operational difficulties could be traced back to nonstandardization of equipment. Finally, a belated all-out attempt at "full" cooperation was made, even to the extent of designing and using common aircraft. However, continued rivalry and discord between the air forces seriously hampered even this final effort, as is evidenced in the development of jet- and rocket-propelled aircraft.

Steps Toward Cooperation

Before the war, the joint Army and Navy Committee was created, and although this encouraged some cooperation and exchange of technical knowledge in many fields, no striking results were noted.

In 1942 the Army-Navy Air Committee was formed in view of the urgent necessity of expediting the solution of the increasing wartime problems. Efforts were generally limited to research, with negligible results.

Finally, in 1943, in answer to the ever-increasing burdens being imposed upon the manufacturers, and in view of the shortage of materials, it was realized that the most vital problem was the necessity for a certain degree of uniformity between army and navy equipment. The previously formed Air Committee was replaced by the Army-Navy Technical Committee established by the chiefs of the Army and Navy Air Headquarters. Proposals were studied for joint research, design, and production of weapons and equipment. There were a few specific joint achievements in the field of research, but due to persistent disagreement on ideas, full cooperation was never attained.

Factors Hindering Standardization

Some high technical officials believed that unification in the early stages of research would take away the rival spirit and thereby reduce efficiency. This was possibly true in some fields of basic research, but the Army and Navy maintained one-sided opinions right through to the end of the production line.

Due to the late start toward cooperation in design, extensive joint use of weapons and equipment would have proven impractical. The already widespread operational use of individual designs prohibited standardization without comprehensive reequipment of units. Even standardization of simple aircraft components was hampered by the following factors:

The Army Air Force used a 24-volt electrical system since 1938. The Navy did not switch to the 24-volt system until April 1945, and even then production was limited to two types of aircraft.

Aircraft machine gun ammunition could not be used jointly due to differences in gun barrel chamber dimensions. Variations in the design of existing amounts precluded joint use of most aerial weapons (guns, cannon, and rocket-launchers).

The late initiation of joint design and production on new models of equipment was far from the solution, as these new standard types represented but a small fraction of the total operational equipment.

Any attempt at large scale reequipment of units with standardized weapons would accrue disadvantages far outweighing the potential gains of joint production. Some of the factors involved would be:

Major modifications of equipment and installations.

Retooling of factories.

Immediate or gradual replacement of large existing stocks, further complicating the already complex supply problem.

Retraining of personnel in operation and maintenance.

Revision of existing tactics.

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Repercussions in the Combat Zones

In addition to numerous efforts at combat cooperation being nipped in the bud by nonstandardization of aircraft components and weapons, many sustained joint operations were seriously hindered:

Due to differences in cruising ranges of Army and Navy aircraft, coordinated operations, particularly in sea warfare, were relatively ineffective. An example is the futile attempt of the Army to provide satisfactory fighter cover for the naval special attack corps in the Okinawa campaign.

Major differences in radio equipment design resulted in poor intercommunication between Army and Navy aircraft.

Due to variance in design of Iff equipment, accurate identification of both Army and Navy aircraft was often impossible.

Direct lack of coordination was also evident in combat. During the Okinawa campaign nine flying regiments of Ki–67's were scheduled for torpedo operations. The Navy furnished the torpedoes but no personnel to assist in their adjustment. As a result, only two of the regiments were able to go into combat, and the remaining units were later returned to normal bombing operations.

III. TECHNICAL AID FROM GERMANY

General

Outside aid to the pre-1941 Japanese war machine was not limited to German assistance. Quantities of aircraft instruments and components were purchased from other powers, including the United States. In Toyokawa arsenal, the Navy's most important aircraft gun and ammunition plant, there were installed equal numbers of both German and American machine tools.

Prior to and during the early period of the war, German assistance was generally limited to granting permission to the Japanese to purchase specimens of standard aircraft and equipment. The planes were generally used for study and experiment; but other items, such as instruments, were released in quantity for operational use.

The most active investigation of German aircraft materials and aeronautical data was launched during the period 1939 to 1941. Investigation teams were formed with Army and Navy personnel as heads and including civilian representatives. These groups visited key German factories, studied design and production techniques, and brought back specimens which were subject to intensive study. In addition, civilian technical representatives of firms like Mitsubishi received aeronautical data from military attachés After Pearl Harbor, the dispatching of such teams was necessarily halted, and such cooperation was thereafter generally limited to undetailed military cables.

Germany was reluctant to cooperate wholeheartedly with the Japanese. Despite early liaison, it was not until late in 1943 that concrete assistance was given and Japs finally permitted to enter the Luftwaffe's "Wright Field" at Braunschweig. Even then, much information was withheld, and Japanese admission was limited to very few German installations. Eventually, in January 1945 by an order from Hitler, top secret experimental information on radar, guided missiles, and jet propulsion was finally released. However, many of these belated consignments, as with some earlier transfers, were lost while en route by blockade-runner to Japan. In the case of the Me–163, complete specimens and details were released to the Japanese military attaché, but only undetailed data ever reached Japan.

Channels of Supply

The main supply channels for interchange of information and matériel between Europe and the Far East were:

Blockade runners, both surface and submarine.

Mail by courier and parcel post, presumably through diplomatic channels.

Rail communication through Siberia.

Quantity traffic by rail across Siberia was closed with the opening of the Russo-German war, but nevertheless, passage of personnel still continued after that date.

In addition, the use of long-range aircraft was fully considered. One Italian aircraft in 1941 made a round trip flight to Tokyo. Thereafter, Germany negotiated for the opening of a northern air route between Europe and the Far East. Japan, however, opposed this in favor of a southern route to avoid infringement of Soviet neutrality. Because of this difference of opinion, and the lack of long-range German transports, no such flights were carried out.

In the period 1941–43 a large volume of two-way shipments was carried out by surface blockade runners. The cessation of surface running and the subsequent loss of French Atlantic coast ports to submarines greatly restricted interchange of matériel and information during 1944–45. Although some submarines successfully made the trip during this latter period, the limited cargo space available restricted the material sent to Japan to blueprints, plans, small prototypes, and special materials carrying the highest priority. Unfortunately for the Japs, the severe restrictions in blockade running coincided with German's release of the most important weapons.

Reciprocal Aid

The Germans expected little or no return of technical assistance. (Exclusive of torpedo weapons, Japan's contribution was almost entirely raw materials.) Information concerning the Ta bomb had been voluntarily transferred, but was never adopted by the Luftwaffe. However, in the middle of 1944, urgent but futile requests were made for available Japanese antibomber weapons. Major Kobayashi, JAAF liaison engineer in Germany since 1941, was unofficially approached by General Marquat about such Nipponese developments but the Japs "had no suggestions of any kind to offer." (Kobayashi, incidentally, had purchased the manufacturing rights for the electric primer, including drawings, chemical samples, and jigs. These items, however, shipped by submarine, never reached Japan.)

JAAF Purchases

Some of the material received by the Japanese Army Air Force included:

Specimen aircraft:

Focke-Wulf 190.
Messerschmitt 109.[1]
Messerschmitt 210.[1]

Aircraft guns:

7.92 mm. machine gun (Mg–15). Produced as the Type 98.

13 mm. machine gun (Mg–131).

15 mm. machine gun (Mauser Mg–151/15).

20 mm. machine gun (Mauser Mg–151/20). 800 of these guns, purchased along with 400,000 rounds of German ammunition, were shipped by blockade runner in November 1943, subsequently installed in the Ki–61 (Tony), and employed in combat.

Bombsights:

Lotfe 7C and 7D (Zeiss).

JNAF Purchases

The Japanese Naval Air Force also utilized the Daimler-Benz design in the construction of their Ha–60 Atsuta engines (model 21–Aeia=1,185 horsepower; model 31–Aeip=1,380 horsepower; model Aeit=1,480 horsepower). The presence of three Daimler-Benz company technical representatives in Japan during the entire war accounts for the extensive use of this design.

The following additional purchases were completed:

Specimen aircraft:

Junkers 88. Used as a model in the original plans for the Ginka (Frances) medium bomber.

Aircraft guns:

7.92 mm. machine gun (Mg–15). Produced as the type 1.

7.92 mm. machine gun (Mg–17).

13 mm. machine gun (Mg–131). The Japanese Navy's type 2 machine gun and ammunition were close copies of the German specimens, but the electric primer was not employed.

30 mm. machine cannon (Mk–108). In the spring of 1944, the GAF presented to Japan as a gift, two Mk–108's and sample ammunition. Thereafter, both the Army and Navy became active in negotiations for further guns and ammunition of this and the Mk-103. Specimens were released in Germany: One Mk–108, 23 cases of ammunition and drawings were captured on the U–234; other samples are believed to have been sunk en route to Japan.

The jet and rocket propulsion program was based on meager information received of German operational types:

Shusui=version of Me–163.
Kikka=version of Me–262.
Baika=version of Fzg–76 (V–1).

Joint Army-Navy Liaison

A joint army-navy technical committee was founded in Japan to coordinate all German technical material for both the army and navy; but, despite this set-up, duplication of inquiry continued. The Germans commented on this state of affairs, pointing out that they had no intention of making agreements separately with the two services, and that it would seem advisable for one service to take complete charge of negotiations.

[1] Guided by the design of this Daimler-Benz engine, and by additional specimens of the Db–603; the Ha–40, Ha–140, and Ha–240 were test produced. The Kawasaki liquid-cooled engine Ha–40 (used in the Ki–61 [Tony] is an improved copy of the obsolete German Db–601 for which manufacturing rights were purchased in 1939. Prototypes of later type German engines never arrived in the Far East.

As the result of later discussions, it was decided in the field of jet propulsion that the Navy would assume responsibility for negotiations with Germany. In spite of this understanding, however, the Army continued to maintain direct contact with the Germans.

German Raw Materials

Varying quantities of mercury, special steels, aluminum, lead, platinum, industrial diamonds, ball bearings, and industrial chemicals were purchased by the Japs and shipped to the Far East.

IV. AIRCRAFT

General Concepts

The Japanese desire for light, maneuverable fighters resulted, initially, in short-range types. Due to the brief distances involved in the pre-Pearl Harbor conflicts on the Asiatic Continent, the Japanese bombers, too, were planned with a short operational radius. Even after the initiation of the Greater East Asia War, range was not materially increased. As a result, the Japanese Army Air Force was incapable of attacking our long-range bases (i. e., B–29s on Marianas). Due to the exigencies of the sea operations, the range of most Navy aircraft was superior; but the Japanese offensive complex seriously handicapped navy reconnaissance when the tide turned, because of the unsuitability of these offensive aircraft to the reconnaissance role.

There was a dire need for a satisfactory long-range bomber. The new Army heavy bomber, type 4 (Peggy), was typically uneconomical. The original plans called for a bomb capacity of 3,000 kilograms (6,615 pounds). The final model permitted only a 1,000-kilogram (2,205 pounds) bomb load; less than half of the B–26 capacity. The air forces of the Japanese Army and Navy suffered a vicious limitation in air warfare, resulting from the lack of a satisfactory long-range bomber on relatively equal terms to the opposing air forces.

Though operational Japanese bombers were generally limited to the direct supporting role of surface forces, it was soon realized that a large strategic bomber would be advantageous. A super-bomber (Fugako) was designed which was capable of attacking the industrial centers of the United States, but the plan was dropped when the Ministry of Munitions calculated that, due to the raw material shortage, such production would interfere with the more essential new model fighters. Nevertheless, just prior to the war's end, the Army and Navy combined effort to produce a new long-range bomber; which, however, arrived too late.

Armament and Armor

In the early stages of the war, the prevailing dogfights made a highly maneuverable fighter quite advantageous. Early fighter types had no armor plate and the Japanese pilots often removed wing guns in order to increase maneuverability. However, when pilot quality deteriorated and losses were high in 1943, it was decided to apply armor and leakproofing to all new designs. At this same period came the trend toward heavier firepower.

Japanese bombers, likewise, started out underarmed and remained so throughout the war. Their use of single .30 or .50 caliber flexible guns as a defense against American fighters mounting four to six heavier guns, paralleled the situation found earlier in the ETO where the Eighth AF heavies had to bear the brunt of attacks by heavily armed German fighters with far superior firepower.

The Japanese lack of bulletproof tanks was a serious handicap especially in view of the Allied emphasis on incendiary ammunition. The Japanese gave up the possibility of a successful leakproof tank as a futile quest. After unsuccessful combat tests of various types, most tanks were abandoned as too complicated and troublesome. The best leakproof types were too heavy and bulky for the light airframes.

Engines

Japanese engines offered the most prominent performance handicap. Even when basically sound in design and satisfactory in original form, the mass produced engine was often the most serious deficiency of the Japanese aircraft. The quality of factory workmanship had deteriorated to such an extent in the final months of the war that the naval air arsenal undertook to reinspect minutely as many engines as possible before installation on aircraft.

The Nakajima 1,800 horsepower radial, air cooled engine is a compact, high-power unit and its designers, as well as the manufacturers were given technical honors. The amazing performance data caused both the Army and Navy to vie for this engine. The production at the Musashino factory was pushed. The Army fitted this engine

to the newest fighter, type 4 (Frank), but the production result, not only fell below the performance expectations, but it also introduced serious maintenance problems. The Navy, too, tried using these engines on their best planes and encountered similar problems.

Patent rights for Kawasaki's liquid cooled 1,350 horsepower, inverted V engine were originally bought from Germany and the engine manufactured at the Akashi plant. Difficulties in this production held up the operational use of the type 3 fighter (Tony) and the inherent defects of the engine seriously handicapped the fighter's performance. Finally, the Tony was hurriedly equipped with the Mitsubishi 1,350-horsepower engine. This aircraft demonstrated excellent combat capabilities during a carrier attack on Kyushu. Minus the early engine difficulties, the Tony probably would have proven highly efficient in the Philippines and Okinawa campaigns.

Small model "0" high-horsepowered engines especially proved unreliable. Mitsubishi had a 2,200 horsepower, air-cooled engine, in this category, which passed acceptance for use in the new type, long-range heavy bomber. Due to difficulties with the engine, the bomber was delayed an additional 6 months thereby precluding its use in attacks against the Marianas.

Considerable progress was made by the Japanese during the course of the war. Despite this advance, however, Jap engine performance continued to lag far behind that of the United States. This deficiency in turn inflicted severe limitations on armor and armament capacity (figure T).

High Altitude Supercharger Development

Turbo-supercharger.—Basic Japanese research was initiated by the Army about 20 years ago, when one turbo-supercharger purchased from France was subject to numerous ground and air tests. However, after a short period of experimentation all interest was abandoned.

More than 10 years elapsed before interest in the turbo-supercharger was reinitiated by a civilian agency, Mitsubishi Heavy Industries, in 1937. In 1940, military research was revived with studies of two foreign turbo-superchargers, the American Moss and the Swiss Brown ball-bearing type. All Japanese supercharger development lagged, but Mitsubishi, far ahead of the Army and Navy, produced two prototype (1000 horsepower) turbo-superchargers. However, performance demand of aircraft had by then risen, so these early models were never installed and consequently further production was abandoned.

However, research was spurred on by the receipt of reports of successful American installations in the B–17 and P–43. By the end of 1942, Mitsubishi produced components for ten 1,500-horsepower turbo-superchargers, designated the Ru–302. The first of these having passed the endurance test in the Spring of 1943 were assembled and five each supplied to the Army and Navy. Eventually in April 1944, they were put into production and about 250 of them were manufactured by the end of the war.

The prototype of the 2,000-horsepower model, the Ru–303, was completed by the end of 1943. After 1 year, 15 were completed and distribution was made: 10 to the Army; and 5 to the Navy. Production began at the end of 1944 and by the close of the war 100 were produced.

Two-stage supercharger.—Research on the two-stage mechanical supercharger began in 1937. Both the Army and Mitsubishi studied the French Falcon supercharger. The design and construction of a test model was completed in 1939, but as numerous metallurgical problems arose, the research was temporarily halted. In 1941, in view of the relative advances in turbo-supercharger development, the two-stage type was considered a secondary project. Later experimentation, using the Rolls-Royce engine as a test model, was undertaken but never reached perfection. Nevertheless, it was hoped to have a prototype installation on the Shiden navy fighter by the end of 1945.

Ru–302 turbo-supercharger vs. single-stage two-speed type.—Raiden: With the Ru–302 at low altitudes, the maximum speed fell about 20 knots (23 miles per hour). As the altitude increased, the difference decreased, but up to 7,000 meters (22,967 feet), the speed was still below that of the single-stage two-speed supercharger installation. Under ideal conditions between 9,000 meters (29,529 feet) and 11,000 meters (36,091 feet), an increase of 15 knots (17.28 miles per hour) was registered. This unsatisfactory performance resulted in the abandonment of the installation.

Ki–46 type IV: On this twin-engined fighter (originally designed for reconnaissance) at 9,000 meters the turbo-supercharger raised the speed from 314 to 341 knots (362 to 393 miles

per hour). The rate of climb up to 10,000 meters (32,810 feet) was about the same for the two types of superchargers.

Planned installations.—Due to the frequent occurrence of problems with the engine proper, aggravated by lack of supercharger installation technique, the turbo-supercharged engine never became operational. By the end of 1945, however, it was expected that installation would begin on the following aircraft types:

Ki-46, type IV (Ru-302).
Ki-83, (Ru-303).
Ki-74 (Ru-303).
Reppu (improved type) (Ru-303).

It was also desired and planned to install turbo-superchargers on the following additional aircraft:

Ki-87.
Ki-94.
Ki-100 (model 2).
Ki-102 A.

Conclusion.—(1) The use of high altitude superchargers on operational aircraft could have raised the critical altitude rating from the present average of 6,000 meters (19,686 feet) to an average of 8,000 meters (26,250 feet) with two-stage superchargers, and to an average of 10,000 meters (32,810 feet) with turbo-superchargers; the maximum critical altitude predicted by the Japanese was 11,400 meters (37,400 feet). With the limited boost pressures used in Japanese engines, these high figures were quite possible.

(2) The failure in early development of a suitable high-altitude supercharger, along with the generally poor performance of the engine, not only handicapped existing tactics, but, furthermore, precluded the operational use of many potentially effective and highly developed anti-bomber measures, including air-to-air bombing, parachute bombing, and cable bombing.

Fighter Concept and Development

In January 1938, at a combined military and civilian research meeting sponsored by Mitsubishi, it was decided that maneuverability should be given first consideration in fighter plane design. Thus was initiated the emphasis on the advantageous dog-fight tactics with little provision for self defense. The early Jap successes seemed to confirm this theory. With but scant recognition of Jap numerical superiority (Figure A) and the excellent battle-trained pilots, almost all the credit was given to the Zeke, which was more maneuverable and could climb higher and faster than opposing types. All forward planning of fighter aircraft was fatally delayed by this early and sustained belief by the General Staff in the invincibility of the Zeke, especially in view of its low rate of operational losses. Up until near the end of the war, despite increasing Allied success in attack and retrieve methods, this now obsolete tactical concept was adhered to religiously. Maintenance of superior maneuverability imposed grave handicaps upon armor and armament. As the war progressed the need for greater fire power and defensive armor became more and more evident.

Steps were finally taken to increase the armament; but the inherent increase in gross weight and drag cut down on the performance so materially that engine power had to be increased. Despite numerous power plant modifications which increased field maintenance by many hours, in addition to increasing production time and delaying new types, it was usually found necessary to design a new improved engine.

Often, army and navy requirements on speed, range, and maneuverability so exceeded the factory capabilities that much time was lost. (In the case of the Ki-83 two years elapsed due to this lack of a concrete plan. The first instructions were issued in May 1941, but it was not until May 1943 that the final plan was reached and an experimental order issued.) Much was learned from the numerous combat trials of the many modified types and these lessons were later embodied in new and more efficient designs. However, the great majority of these more satisfactory production models were not decided upon until just before the closing of the war.

The naval arsenal design staff had early envisaged the need for a successor to the Zeke, and had in mind a fighter like Sam. When the General Staff finally saw the need for replacement, it was found that engine design was lagging behind that of air frames so that delay in building a properly engined test model of Sam resulted. George 11 was finally pushed into combat as a stopgap. Later, despite delays in developing George 21, the parallel work on Sam lagged even farther behind, thereby forcing the mass production of the former. This production stage, however, was reached too late to be of practical assistance in stemming the rising Allied air power. Likewise, turbo-super

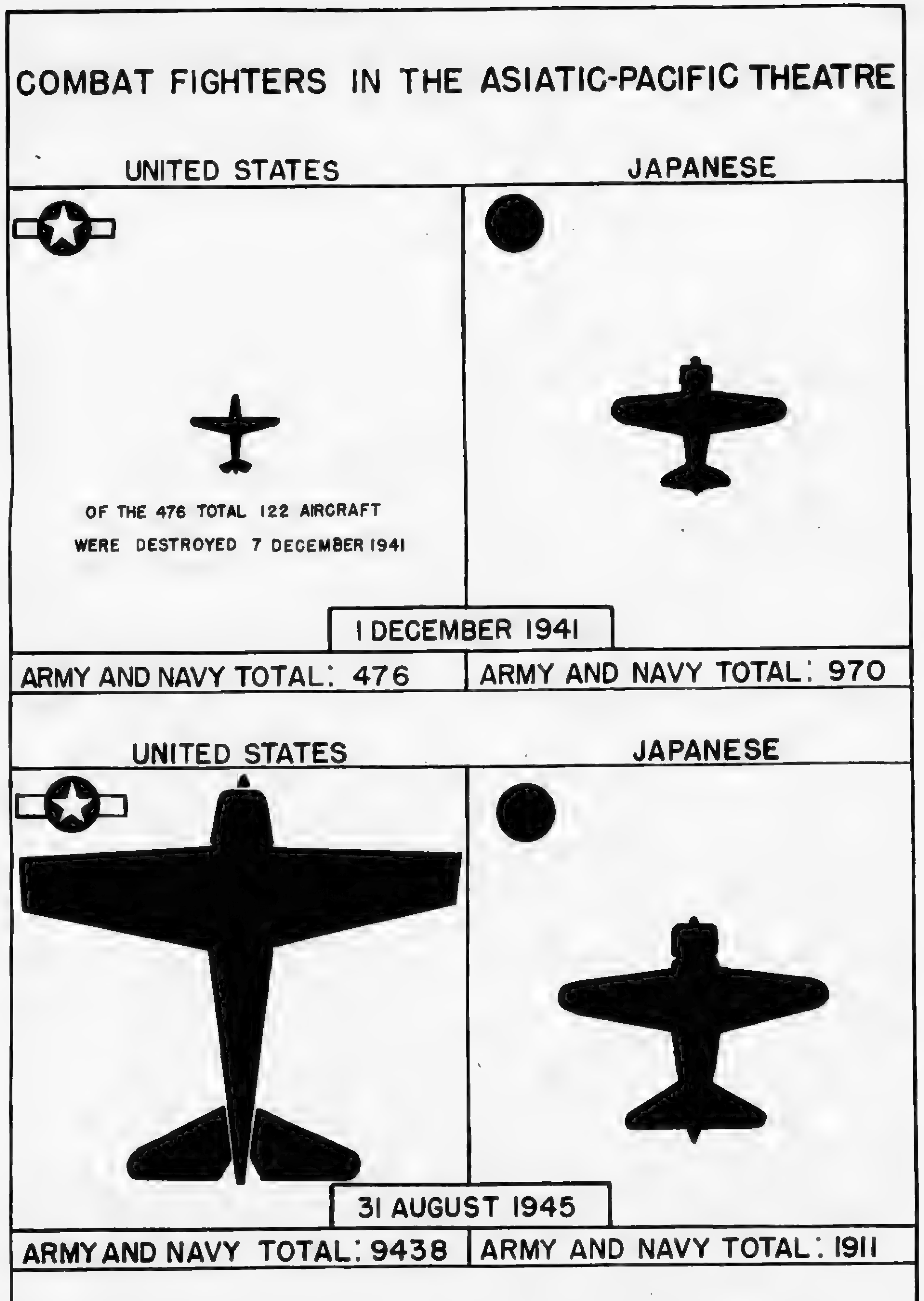

FIGURE A

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charger problems on Jack and engine problems on the Zeke 64 made these two aircraft ineffective. Development of twin-engined interceptors was equally discouraging because of the insufficient speeds attained, and soon fuel and engine production made the two-engined fighter uneconomical for further trial. The Denko was expected to fill the long felt need for a pure night fighter but was fatally delayed due to poor initial airframe design by the less efficient Aichi organization.

Though basic aircraft design was not always inadequate, the mass product was often of poor quality. This fact, coupled with the ever increasing Japanese use of substitute materials and low-octane fuel, made it almost impossible to improve performance of existing types.

Nevertheless, the continued belief in the invincibility of the light maneuverable fighter resulted in unreasonable demands for the modification of these operational types in efforts to cope with new Allied aircraft. The outcome was that the rapidly multiplying modification problems gave priority on technical research to the old models, and fatally delayed the development of urgently needed new types (Figure B).

Heavy Bombers

The first operational four-engine bomber, the Shinzan (Liz), was abandoned in December 1941 due to its failure to meet the planned requirements. The radius of action was shorter than anticipated and the top speed was inadequate. The production results of the most recent heavy bomber, the Rita, indicated that the building of heavy bombers might be beyond the scope of the Japanese aircraft industry, since little volume could be expected from inadequate production facilities.

Nevertheless, the construction of superbombers was contemplated in 1943 by both the Army and Navy, with the view of bombing the United States. This six-engine bomber, the Fugaku, designed by Nakajima, was to be capable of carrying 4 metric tons (8,800 pounds) of bombs over a 10,000 mile range of 13,000 meters altitude (42,650 ft). It was to be slightly larger than the B–29, with a wing span of 60 meters (197 ft). The planned speed at altitude was to be 650–680 kilometers (404–423 miles per hour) per hour.

The Army's plan was for the Fugaku to do strategic bombing in the United States and then go on to Germany. There was to be a crew of only five and the armament was to be negligible. Only two guns, caliber .50 were to be installed; one each in nose and tail turrets with Sperry computing gunsights. It was considered that the contemplated 45,000 to 50,000 ft. of altitude would keep the bomber practically free from interception.

The naval plan was to take off from Misawa field in northern Honshu, bomb the United States Pacific coast, and return home. The Navy's Fugaku would carry a crew of seven, and the total defenses would be four 20 millimeter guns.

The development of the Fugaku reached only the model testing stage. With the front line continually closing in on the home islands, the Japanese decided to follow the example of the Spitfire's defense of London, and emphasis was shifted to fighter aircraft.

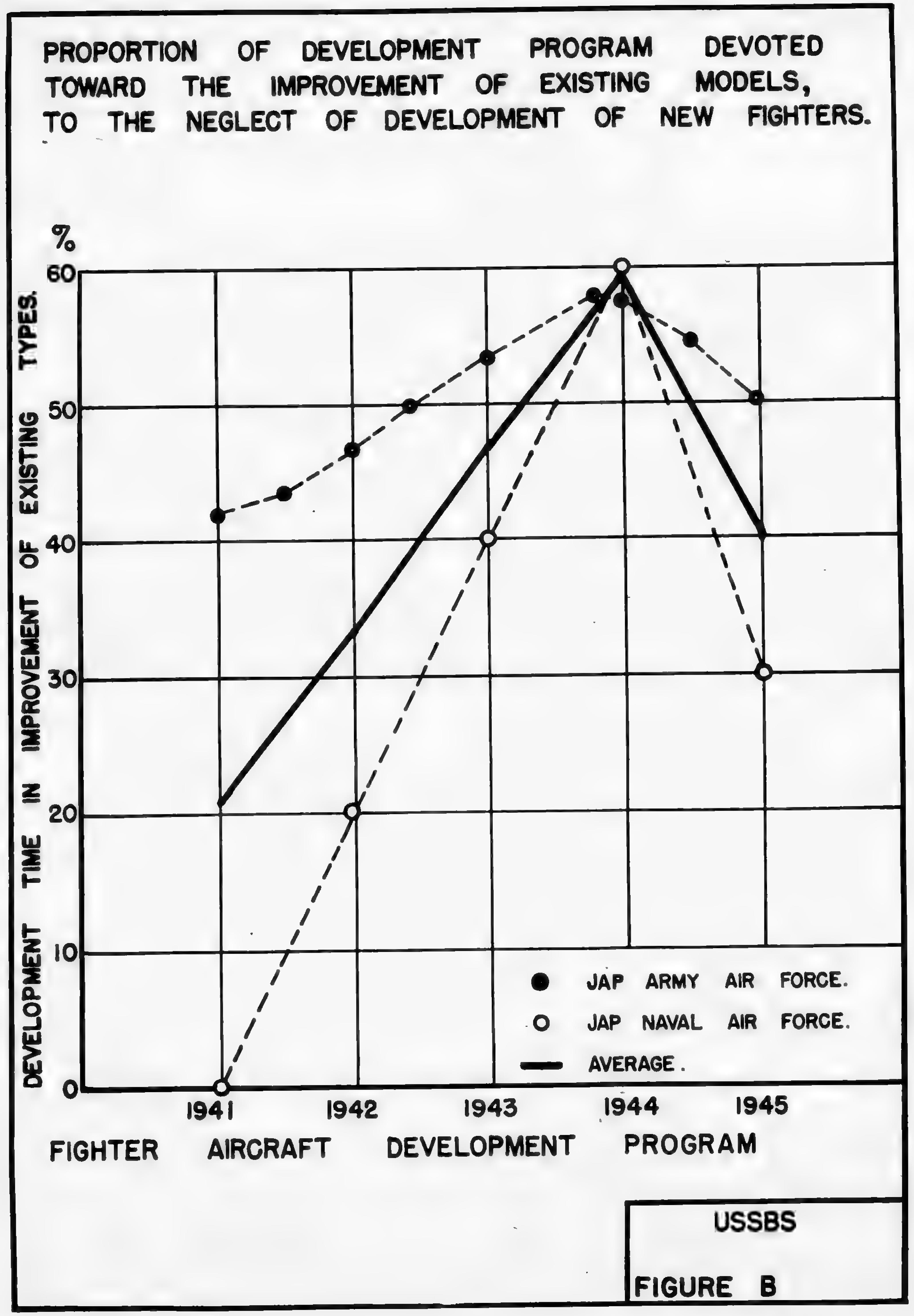
Photo-Reconnaissance Problems

The lack of a suitable fast high-altitude photo-recco was first felt by the Navy in the battles of the Solomons. Army Dinahs at Rabaul were accordingly taken over to provide the needed data. In the final phase of the war in Kyushu, four or five Ki–46's with army crews were placed under command of the 171st air group at Kanoya for reconnaissance duty. The Navy air command, upholding the general Navy viewpoint that army air-crew-navigation training was inferior, claimed that the inaccurate fixes on the sightings of Allied task forces was causing great confusion.

The turn of the war from offense to defense introduced new problems which necessitated the commitment of Myrt to operational use even before it had been flight tested. Plans then centered upon Riyi, in which the fundamentals of Frances were preserved to hasten production. However, with the retreat toward the homeland, the need of a very long range reconnaissance waned and the project was soon abandoned. It was hoped that successful installation of a turbo-supercharger in the Myrt would fill the new requirements, but tests were not completed until the final days of the war.

The Aluminum Shortage

Wooden aircraft.—As a means of meeting the aluminum shortage, it was expected that the inherent craftsmanship of the Japanese woodworking industry could be harnessed to wooden aircraft manufacture. Starting with a wooden training model of Val, the Navy expected to build an operational suicide version, to be followed by



a wooden Betty (Taiyo), Tabby (Dc-3) and Soku, a large 40-ton flying boat. The lack of both current supplies and future manufacturing potential of special woodworking machinery for aircraft construction, however, portended a lengthier and more expensive production program than had been foreseen. The Army succeeded in building an all-wooden fighter, Ki-106; its weight proved excessive, however, and steps were being taken to reduce this weight at the end of the war. Research was also carried out on the construction of wood tail surfaces for other aircraft; and wooden rudders, stabilizers, etc., were tested on operational types. (German assistance was received in the form of special materials and adhesives for wooden aircraft.)

Steel aircraft.—The Navy had steel versions of Frances and Rita on the project board, the metal research being done by Kawanishi. The Army's project for a steel aircraft, Ki-113, was dropped when production facilities appeared lacking. However, practical data was being worked up to utilize steel in the design of parts for other aircraft.

Aluminum from clay.—A Japanese scientist, Professor Iimori, developed a method of extracting aluminum from low-grade ore. From dry loam he was able to attain 7 to 8 percent aluminum. The Japanese Board of Technology examined the procedure, but decided it was too expensive, and the project was suspended.

Alcohol as Fuel

General.—With the reduced petroleum supplies, the Japanese began in October 1944 to adapt their airplanes for the use of grain alcohol (made from potatoes and sugar) to replace gasoline. Alcohol, because of its high-oxygen content, has a heating value much lower than that for gasoline. Nevertheless, because of its ability to withstand a very high compression, and to recover a greater quantity of waste heat during vaporization, it can deliver almost as much power per pound of fuel as can gasoline. Although it has not yet been economically possible to use alcohol in the United States, it has been widely used in Europe and in tropical countries.

Operational use.—The alcohol plants were turning out only enough fuel to supply the trainers when the war ended, and most of the training aircraft had been so converted. It was the intention of the Japanese to convert all types of planes to alcohol except special-purpose aircraft.

Shortcomings.—Despite regulations to the contrary, it was often noted that alcohol fuel supplies were frequently used for drinking purposes by military personnel. In addition, the following aircraft deficiencies resulted from this substitute fuel:

Lower performance.
Greater installed weight.
Increased maintenance problems.
Added operational difficulties.
Reduced range.

V. JET AND ROCKET PROPULSION

General

Japanese research on jet propulsion was begun by the Army and Navy, independently, in 1941 and 1942, respectively. It was not until 1943, after receipt of intelligence reports on foreign developments, that these projects were accelerated.

Joint Army-Navy Efforts (Figure C)

In 1944, interservice cooperation was seen as a dire necessity in order to utilize fully the few available jet technicians, conserve critical materials, and minimize on the number of plane models.

The Ki-201, Kikka (Me-262 type) was almost wholly a navy project utilizing the Ne-20 (Oka 43 type) engine. The Army rendered some little assistance in the preparation of a test model.

In the development of the Ki-200 Shusui (Me-163 type) there is found an all-out effort for full cooperation. Joint research was conducted, and the Army and Navy set up a civilian research committee. The Navy was designated as primarily responsible for the assembly, and the Army was to develop the engine (chemical rocket). During the course of the program, Japanese antiaircraft-force engineers presented some army views on the airframe design, but these ideas were given no consideration in the Navy development plans. The Army, as a result, undertook the design of an improved Shusui called Ki-202. Meanwhile, the Navy initiated a power-plant-development project of its own, and as a result the Army and Navy each came out with separate engines. Though an abortive attempt at coordination, nevertheless, in this project the Army and Navy probably reached the peak of their cooperation.

Tactical Concepts

The primary application of jet and rocket propulsion was toward the development of special attack aircraft. In addition to the operational and pending navy Oka developments, the next important jet project was the production of the Ki-201 (Jap version of the German Me-262). This was considered, in the light of German intelligence reports, to be the most superior of the proposed nonconventional types. In addition to its Kamikaze value against surface vessels, it was planned to profit from the Nazi successes by using it as an antifighter pursuit aircraft. To supplement the special attack role of the Kikka, another Kamikaze jet type similar to the German piloted V-1 was pending development: This was the Baika, still in the design stage. (Not to be confused with the operational Oka "Baka".)

The secondary tactical application was the rocket-propelled B-29 interceptor. This was to be the sole function of the Ki-200 and Ki-202 (Navy and Army versions of the German Me-163).

A subordinate application of the jet engine was proposed by the Navy. This was a plan to utilize the best available turbine-jet engine in the reconnaissance plane Keiun.

Planned Operational Employment

As the Army had the task of protecting the mainland, they were to receive the larger percentage of the aircraft produced.

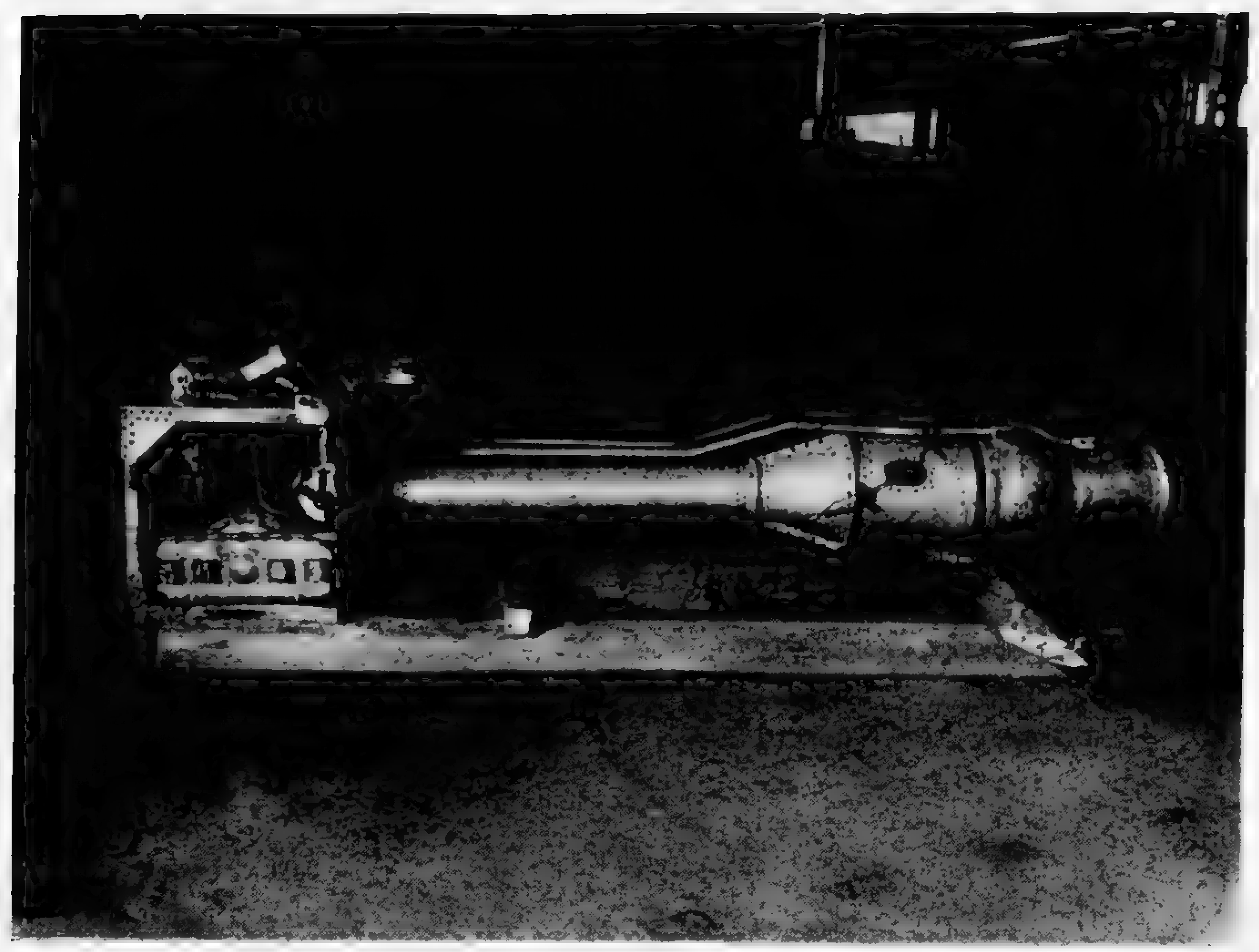
The Army originally planned to use the Shusui (Ki-200) as an interceptor in certain key areas. Experiments were expected to be completed by March 1945, with production between April 1945 and March 1946 totaling 2,400 planes. These Shusui would then be used to activate 10 Hikosenti (36 planes per Sentai) and were to be based first in the Tokyo area; then in the Nagoya-Osaka area, the northern part of Kyushu, and one element in Manchuria. As previously noted, they were to be used solely against B-29s.

Two or three Hikosenti of Kikka (Ki-201) were expected to be activated by March 1946 for use against enemy aircraft and shipping.

Kikka Development

By the early part of 1944, a turbine jet with centrifugal compressor had been completed, later modified by the addition of a four-stage axial flow blower, and designated the Ne-12B. Two Ne-12Bs

SHUSUI



LIQUID ROCKET POWER UNIT FOR SHUSUI

U.S. STRATEGIC BOMBING SURVEY

FIGURE C

were intended to be used in the anti-invasion fighter-bomber Kikka but the airframe was ahead of the engine development. In May 1944, photographic prints of the German Bmw 003 coaxial turbo jet arrived by submarine. (Complete plans were on another which was sunk. Though 40 of the Ne–12Bs were produced, the production was given up in favor of developing a Ne–20 based on the German designed Bmw 003.

In early August 1945, Kikka made a successful test flight using the newly adapted Ne–20. The test results were:

Endurance	*Altitude*	*Speed*
37 minutes	Sea level	603 kilom./hr. (375 m. p. h.)
49 minutes	6100 meters (20,000 feet)	676 kilom./hr. (420 m. p. h.)

Shusui Development (Figure C)

At a conference held by the Japanese Navy in August 1944 the Mitsubishi representative was handed a copy of the German Me–163 manual and ordered to build an experimental Shusui, tailless, single-seat interceptor. The design policy was to copy the Me–163 exactly except as follows: The Mk–103 30-millimeter cannons were to be replaced by the two new navy type 17 30-millimeters; and Japanese Navy instruments and other accessories were to be used.

The first test flight, on 7 July 1945, resulted in a crash landing due to a failure of the fuel feed system. The fuel system was soon corrected, two more were assembled, and several others nearly completed when the war ended. Characteristics for the Shusui were as follows:

Take-off time	11 seconds.
Take-off run	320 meters (1,050 feet).
Level flight range	4 minutes.

The Shusui Ki–200 and Ki–202) was powered by the Toku-Ro No. 2 bichemical rocket which depended upon the reaction of fluid "A" (80 percent oxygen) on fluid "B" (mixture of methanol, hydrogen, and water).

Baika (Figure D)

Research into pulsating-type jets had only just started at the Navy air technical arsenal. Initial tests with benzol as fuel had been made to determine thrust developed, using an auxiliary blower to produce the required flow of air. Provisional plans called for the jet to be used in Baika, the air frame which was to be developed by Kawanishi, and probably closely patterned after the German-piloted V–1. Its primary tactical purpose was to effect Kamikaze attacks against vessels nearing the Japanese mainland.

Outstanding features of this plane were to be:

a. Small dimensions and light weight. Wing area 7.59 M^2, weight 1430 kg. (3,153 pounds).

b. Engine to utilize crude pine-root oil, to offset expected loss of refineries.

c. Simple construction, to offset expected lower skill of workmen.

d. Built of relatively easily obtainable wood and steel, to offset lower production of dural and aluminum alloys.

Keiun

At the time the Ne–20 jet-engine project was initiated by the Navy the Bmw 003 principles were given to Tshikajima-Shibaura Company, Hidachi-Nakajima, and Mitsubishi, and each proceeded independently in the development of the Ne–130, Ne–230, and Ne–330, respectively. These three turbojets were in approximately the same state of completion at the war's end, but none had actually flown. The best of the three was intended to be used on the reconnaissance plane Keiun. This aircraft was originally designed to take the Ha–70 model 01 engine, two conventional Atsutas coupled together, and had actually flown with this unusual installation.

Conclusions

In general, the Japanese may be said to have made fair progress in the field of jet and rocket propulsion despite the following handicaps:

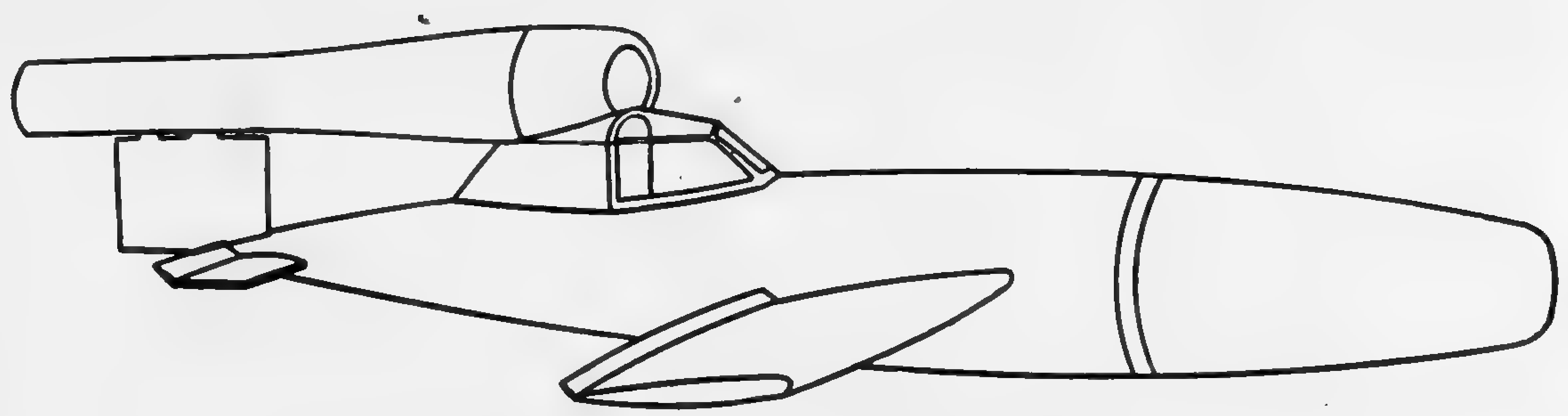
Development programs were initiated at a very late date.

Most specimens and detailed data were lost while en route to Japan by submarine, and little detailed technical assistance was furnished by the Germans.

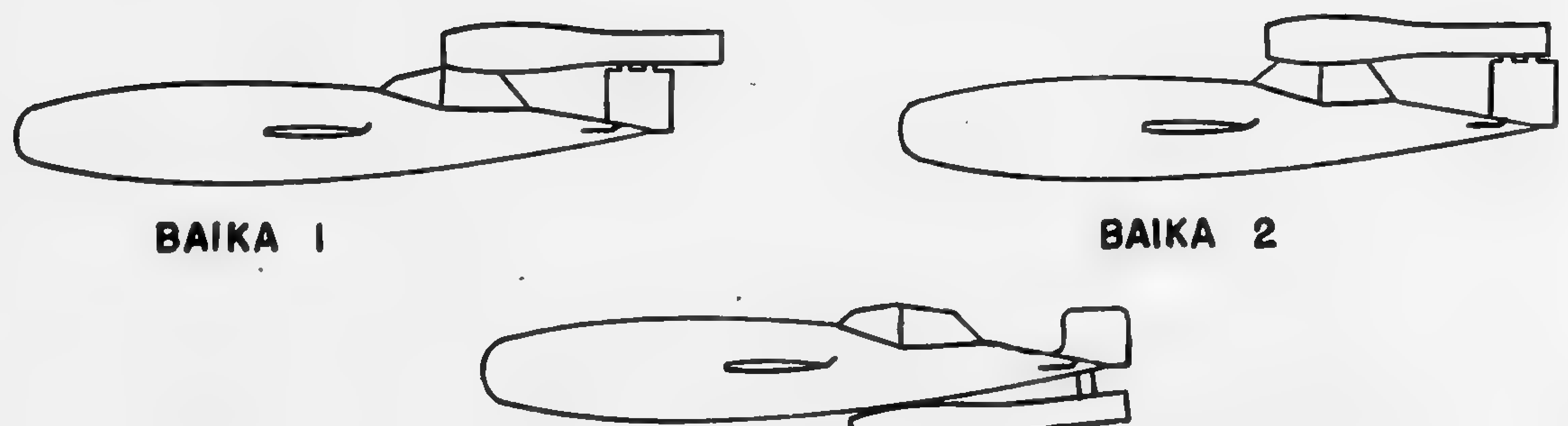
Major metallurgical problems were encountered in the production of metals capable of withstanding the terrific speeds and heat of jet engines.

The administration remained firm in its decision not to interrupt production of conventional engines for conversion to jets.

BAIKA



GERMAN PILOTED FZG-76 (V-1)



SPAN	6.6 METERS
LENGTH	7.0 METERS
GROSS WEIGHT	1430 K.G.
BOMB LOAD	100 OR 250 K.G.

DESIGNS UNDER CONSIDERATION FOR THE BAIKA

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FIGURE — D

Kamikaze Planes

...t engines

Name					Weight	Thrust	Fuel consumption
					Kilograms	Kilograms	Light/hours
Ne-20 (Kikka) (Oka 43)						475	900.
Ne-130						900	1,600.
Ne-230						885	1,630.
Ne-330						1,300	2,530.
Toku-Ro 2 (Shusui)						1500 (4 min.)	T-6.7 C-2.0 (kg/-sec).
TSU-11 (Oka 22)						200	1,200.
KA (Baika)	P				180	300	1,600.
Style 4, No. 1, model 20 (Oka 11).	Solid fuel rocket		1,200	255	115 (Oka X3)	800 (9 sec) (Oka X3)	44 kg (9 sec.).

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VI. "SPECIAL ATTACK" WEAPONS

The Suicide Tradition in Japan

"The quick falling cherry blossom, that lives
but a day and dies with destiny unfulfilled,
Is the brave spirit of Samurai youth
Always ready, his fresh young strength
To offer to his lord."—Ancient Japanese Poem.

From the traditional Japanese cherry blossom was chosen the symbol of Samurai spirit—"willingness to die young and vigorous, rather than to live and fade." The uniforms of the Army and Navy for years have carried conventional cherry blossoms on the badges; and based on this same tradition the name Sakura (cherry blossom) was adopted as the official Japanese nomenclature for the suicide bomb.

Army Kamikaze Concept

Despite the time-worn tradition, General Masaki, who supervised the design of the army suicide bomb, characterized the Sakura as a final desperate, but efficient, measure. "When the degree of mastery of the air is equally divided between the opposing forces, planes should be used for the purpose for which they were originally intended. However, when the strength of the enemy force becomes overwhelming, I believe it is scientifically more efficient to adopt Kamikaze tactics." Towards the end of the war few bombers returned from orthodox attacks, this being the basic reason for the Japanese Antiaircraft Force conversion to Kamikaze.

Navy Kamikaze Concept

The Navy's Sakura (Oka), nicknamed Baka ("fool") by the Allies, was planned following the widespread story of a highly patriotic lieutenant junior grade, Ota, who was said to have sunk an Allied aircraft carrier with a "single strike, crashing his body with his plane." After the Japanese defeat in Saipan, the theory prevailed among the younger naval officers that there was no way to intercept the "tidal attack of the United States fleets" except by executing the "death-defying, body-crash attack." From this idea evolved the so-called Kamikaze special attack forces.

Navy Sakura (Oka) Development (Figure F)

The Navy Oka recorded the most rapid development in Japanese annals. The designers in the first naval air technical arsenal, impressed deeply by Ota's patriotism, worked day and night and completed the design in 1 month. Splendid cooperation was likewise shown between the Navy arsenal and subcontractors, and the experimental model was rapidly built.

The original Oka was to be released from the under part of the fuselage of a land-based torpedo bomber at a point not liable to interception by the enemy deck fighters. If pursued by fighters after release, it could evade them by high-speed diving plus powder-rocket acceleration. It was in reality a high-speed, piloted glide bomb. Some additional features stressed by the authorities were:

(*a*) Ability to sink an aircraft carrier with a "single blow."

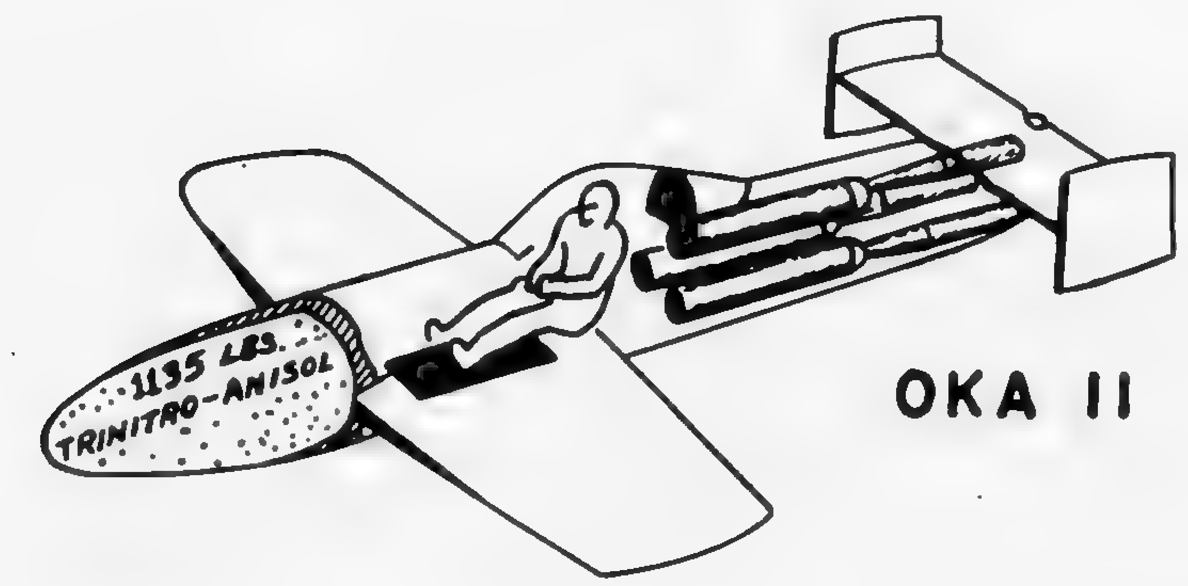
(*b*) Very simplified construction, coupled with use of easily obtainable materials.

Oka 11 (Propulsion: Three solid fuel rocket units).

The initial model was named Oka 11, and production began in September 1944. Strict secrecy was maintained, although the workmen were told the purpose of the plane in order to raise enthusiasm. Within 2 or 3 months it was planned to ship these weapons to the Philippine theater aboard the aircraft-carrier "Shinano," but the plan fell through when the carrier was sunk by a submarine torpedo attack off Tosa.

In the operations off Formosa the Baka appeared for the first time. All the mother planes were shot down by defending U. S. Navy Hellcats, and were unable to get within reach of the United States task forces. This operation revealed the two principal defects: the insufficient range of the missile; and the below-par performance of its mother aircraft, the Betty.

NAVY SAKURA (OKA)



OKA 11

	OKA 11	OKA 22	OKA 43
MANUFACTURER	1ST. NATA	1ST. NATA	AICHI
TYPE	3 SOLID FUEL ROCTS.	TSU-11 ENGINE JET	(TURBO-JET NE 22)
CREW	1	1	1
SPAN	5.0	4.12	9.0
LENGTH M	6.066	6.88	8.16
HEIGHT M	1.16	1.15	1.15
WING AREA	6.00 M^2	4.00 M^2	13.00 M^2
WT. EMPTY	440 KG	545 KG	1150 KG
NORMAL WT.	2140 "	1450 "	2270 "
STATIC THRUST	800KGX9X3	200 KG	475 KG
FUEL CAP. LT.	—	290	400
MAX. SPD. S.L.	—	230 KT/HR.	250 KT/HR.
RANGE S.MI.	20@250(4KM)	70@240(4KM)	150@250(4KM)
BOMB KG.	1200 X 1	600 X 1	800 X 1
WING LOAD	351	363	175

USSBS

FIGURE — F

Oka 22 (Propulsion: Internal combustion engine-jet).

With an eye toward eliminating these defects, a modified type, the Oka 22, was designed. This plane was smaller and lighter than its prototype, and fitted with a "Tsu 11" engine jet. The long-range Ginga (Frances 11), with flying characteristics superior to the Betty, was designated the mother plane. The range of the model 22 was 40 nautical miles (46 miles) at sea level, and 70 nautical miles (80.6 miles) when released from 4,000 meters (13,124 feet) altitude. Fifty planes were manufactured by the designers at the first naval air technical arsenal, but these aircraft never reached the operational stage due to non-completion of test flights.

Oka 30, 40, and 50 series (Propulsion: Coaxial turbo-jet).

In the interim, the development of the 30, 40, and 50 series was in progress. These were all to employ a superior means of propulsion, namely the Ne-20 coaxial turbo jet, the series differences being in the method of launching:

The 50 series was intended to be launched from the parent plane Rita whose development set-backs hindered the progress. Neither Betty nor Frances was deemed able to carry the greater weight of this series. Renzan (Rita), over twice the size of Betty, was designed specifically as the carrier for this Oka 30.

The 50 series had been projected for launching from a towplane. Runways, however, were generally too short to get the Oka air-borne, and this series also made little progress.

The 40 series.—The Oka 43 was designed by the Aichi Company to play the principal role in the forthcoming decisive battle in the Japanese home islands. This model was intended to be launched from a land-based catapult 100 meters (328 feet) in length. Due to its folding wings it could be easily stored underground. Had the war continued, this weapon, with its range of 110–115 nautical miles (127–132 miles) might have presented quite a problem to the Allies.

Oka with floats.—Owing to the nonutilization of numerous Oka 11's, in the Singapore area, due to the lack of parent aircraft, preliminary experiments were initiated in equipping the Baka with seaplane floats. However, the war ended before completion of the tests. These were intended to be posted under cover on the north and south shores at the eastern mouth of Johore Strait, and were to be employed for night attacks against enemy ships forcing their way into the strait.

The short range of the Oka 11 put close limitations upon its tactical value in this capacity. However, the later, longer-range Okas would have been well adapted for such operational modification and employment.

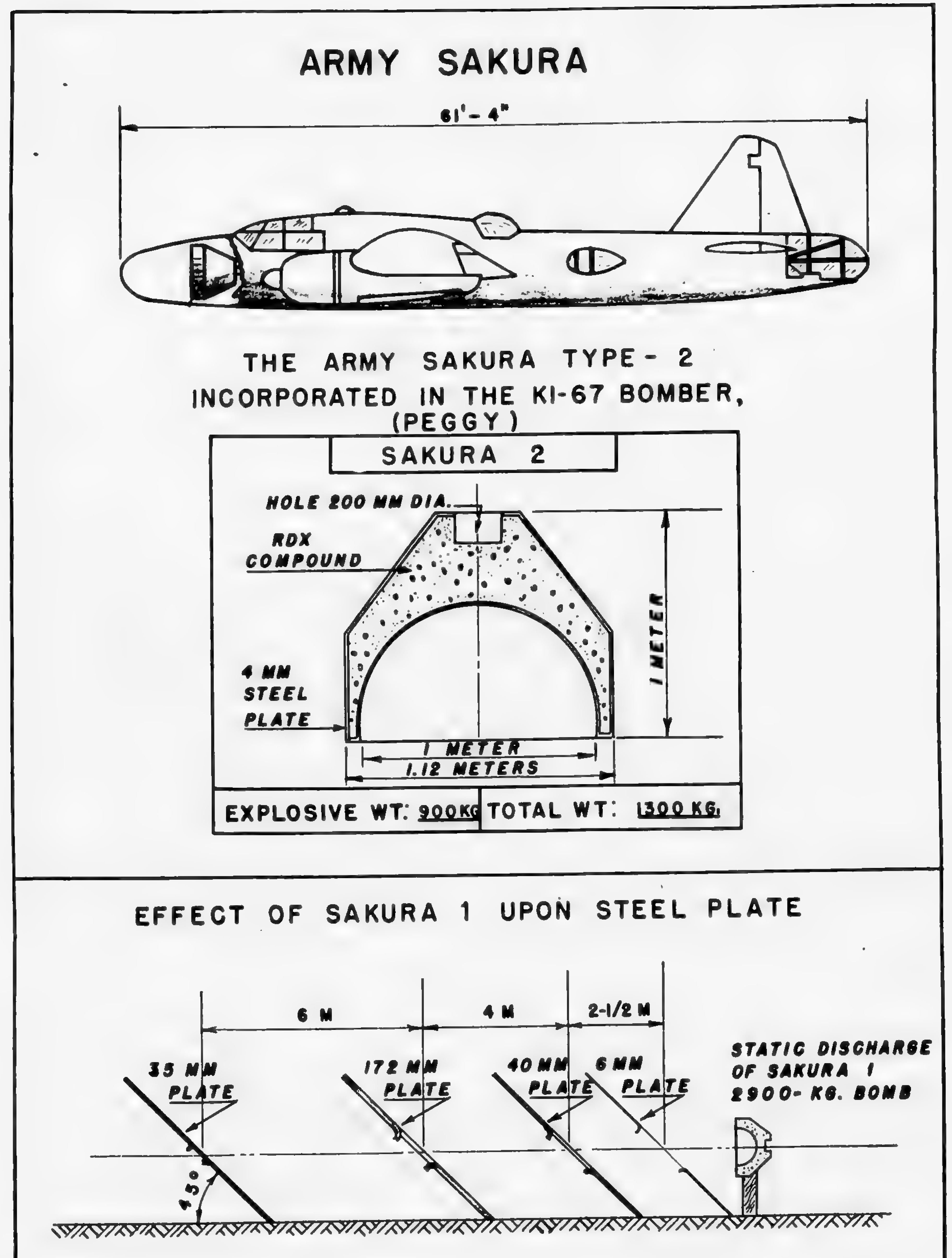
(5) *Training types.*—Modifications of the Oka 11 and 43, both solo and dual versions, were prepared for training purposes by the addition of skids and flaps. The Oka 11 was used, over Yokosuka Airfield, for gliding practice after release from a mother plane. The Oka 43 trainer was to have a powder-rocket (mean thrust 400 kilograms (882 pounds) burning time 9 seconds) installed in the rear of the fuselage in place of the turbine rocket. This latter type was to be catapulted from a rocket-propelled carriage; the launching to be made from a mountain top 600 meters (1,968 feet) above and 3,000 meters (9,843 feet) away from the airfield destination.

Army Sakura Development (Figure G)

The development of an effective suicide bomb was more seriously retarded in the Army, on account of the exaggerated claims as to the results of Kamikaze attacks with orthodox aircraft and ordinary demolition bombs. Repeated reports were received claiming that such attacks had sunk large battleships. It was believed that these false reports were circulated to preserve civilian morale and to uphold the Samurai spirit as well as the Army's reputation.

The Army technicians were convinced that the ordinary Kamikazé could not sink a heavily armored warship without a number of direct hits, and for this reason designed and perfected their powerful Sakura bomb for initial installation in the Ki-67 bomber. However, the continued receipt of false reports made this special weapon appear unnecessary, despite scientific opinion to the contrary. As a result, only a few Ki-67's were prepared and none used operationally.

The Sakura type 1 was a 2,900-kilogram (6394.5 pounds) bomb with a hemispherical-shaped hollow charge. Extensive tests resulted in a very effective design possessing exceptional armor-piercing capabilities. The results of tests by the Army at Mito indicate that the Sakura, when



USSBS

FIGURE — G

detonated statically, had the following characteristics:

Penetrated simultaneously four steel plates of 6, 40, 172 and 35 millimeter thickness, when detonated at an angle of 45° (see diagram).

Penetrated simultaneously two steel plates of 240 and 400 millimeter thickness, when detonated at an angle of 45°. The resultant hole was 400 to 500 millimeters in diameter.

Penetrated simultaneously four steel-reinforced concrete walls, alternately 1 meter (3.28 feet) thick and one-half meter (1.64 feet) thick. The distance between the first and last walls was 18 meters (59 feet).

A modified model, the Sakura type 2, was designed to make a more compact warhead in order to fit the limitations on size because of the aircraft. Its effectiveness was somewhat less than Sakura 1. Although it could penetrate the reinforced concrete walls (c) when detonated 90° to the wall, it could not penetrate the fourth wall when detonated at an angle of 45°. The weight of the Sakura 2 was 1,300 kilograms (2866 pounds).

Conventional A/C Modified For Kamikaze Operations

Aside from early impulsive suicide attacks, it was initially planned to utilize training types and obsolete operational models for Kamikaze. Ordinarily, the fighters would carry a single 250-kilogram (551 pounds) demolition bomb, whereas aircraft of the Ki–51 class often carried a total of 800 kilograms, (1764 pounds). Omitting the arming-wire extension leading to the pilot's compartment, these conventional aircraft were generally unmodified.[1]

Probably the only major "no return" mission modification was found on the Judy 43. This single-seat version, employed in attacks against task forces, was fitted with accelerating rockets whose boost increased the speed by approximately 35 knots (40 miles).

The Seiran submarine-borne float plane with a bomb load of one 800-kilogram (1764 pounds) bomb and capable of good performance, was a potent Kamikaze weapon which was used in I–400 and I–401, and being installed in I–402 (three per submarine) and I–14 (two per submarine) (Figure II). A special 30 meter (98 feet) catapult was built into the submarines. Removal of the floats was planned to improve performance in future "no return" missions. (The Nanzan, a land-based version, was constructed to simulate the launching condition in initial pilot training for catapulting.)

Pending Kamikaze Developments

Development trends were in two principal directions:

Utilization of available materials.—In this category were all-wooden aircraft, such as the Val. Efforts to utilize stocks of obsolete engines resulted in the roughly constructed Toka, a naval copy of the Army Ki–115.

Application of jet and rocket propulsion.—In these development projects we find a belated and unfruitful attempt at "full" cooperation between the Army and Navy:

Kikka (Nakajima design).—Twin-engines jet aircraft planned for use as an antiinvasion suicide bomber. The bomb capacity was 500 kilograms (1,102 pounds). (This design was based on the German Me–262.)

Baika (Navy and Kawanishi design).—Research was being made into the pulsating-flow propulsive duct. Had this athodyd jet been developed successfully, it probably would have been used in considerable numbers as a piloted suicide weapon, having the great advantage of simplicity of production. (This was modeled after the German V–1.)

Tactical Effectiveness

In contemplation of the forthcoming invasion of the home islands, Lieutenant General Tazoe estimated, based on the Leyte and Okinawa experiences, that one out of four planes would sink or damage an Allied ship. This assessment gave due consideration to anticipated employment of all classes of aircraft coupled with the use of ordinary demolition bombs.

Evaluation of Suicide Tactics

It is evident that a skillfully designed and tactfully employed suicide weapon may, in the long run, result in greater efficiency, due to the many advantages, some of which follow:

Greater potential damage to the target, per aircraft attacking, due to the applicability of very

[1] In the final stage of the war, all available aircraft had been prepared for "special attack." An Army unit at Itami, alerted to attack an expected Allied flotilla on 17 August 1945, loaded Ki–61 fighters even to the extent of placing bombs in the cockpit with the pilots.

SEIRAN HANGAR AND LAUNCHING CATAPULT

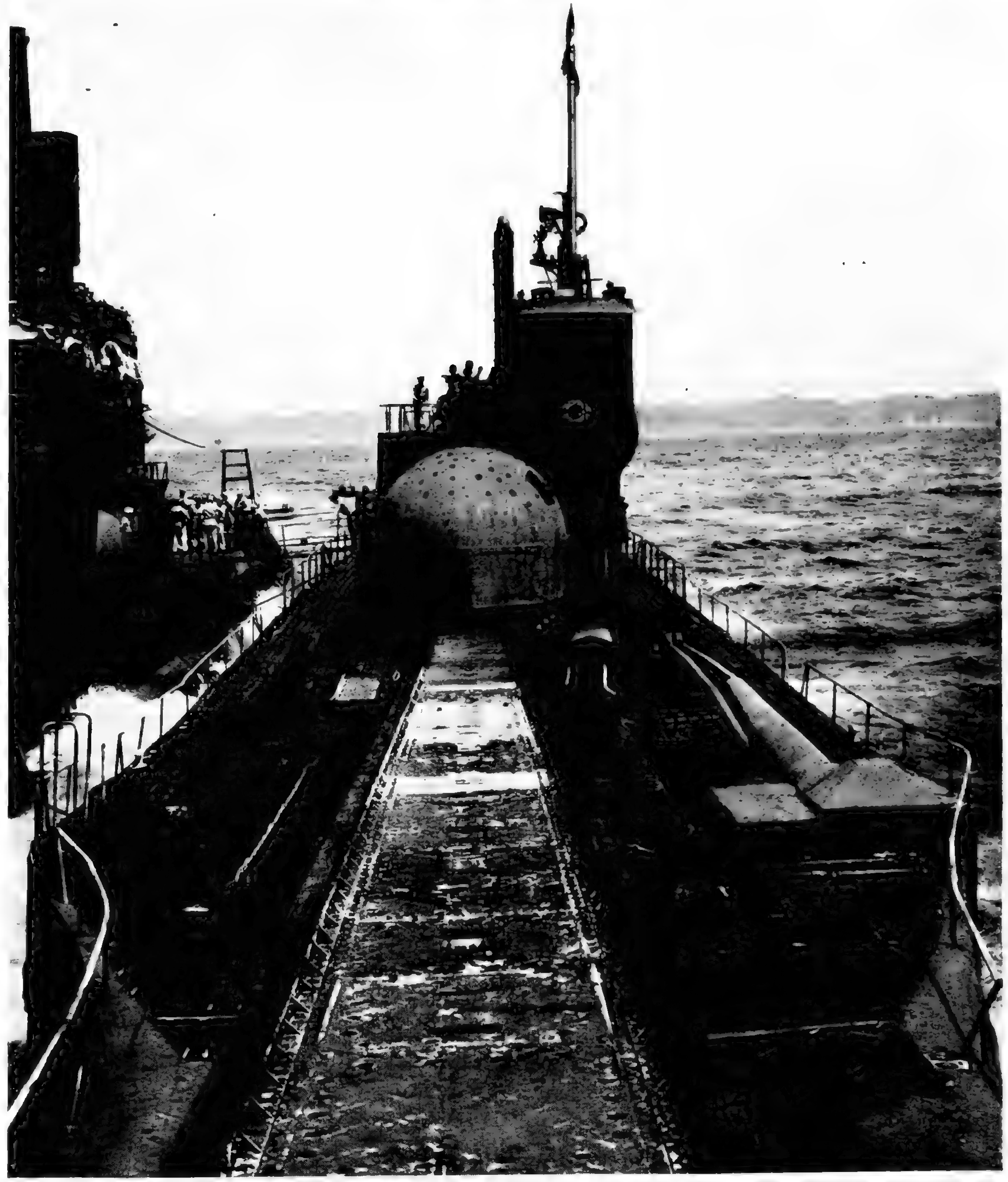


FIGURE II.—On the Japanese Submarine I–14 (Housing two Seiran float planes). The I–400 (at left) houses three float planes. These subs displace 5,000 tons and are believed to be the largest in the world.

large bomb loads, or by the optional employment of special bombs of the Army Sakura variety.

Alternate possibility of super-long-range on "no return" missions.

Comparatively little training required for direct hits, due to the proximity of the attacker and the relatively large target.

Greatly increased aircraft production, due to generally simpler design, and elimination of fire control and other equipment, coupled with the applicability of short life substitute materials.

Wider field of tactical employment, due to the elimination of the need of return landing fields, plus the possibility of surprise launchings from parent ships or aircraft, or from unpredictable land or water locations.

Deficiencies in Japanese Planning

Despite the Sakura tradition, late planning in suicide tactics on the part of the Japanese initiated a great loss of efficiency due to the following weaknesses:

Use of highly vulnerable aircraft of poor performance, resulting in a correspondingly low percentage of strikes.

Lack of careful consideration of weapons vs. target vulnerability. (Use of relatively inefficient demolition bombs.)

Operational use of unperfected new weapons too early in the development stage, as with the Oka 11 (range too short, and parent aircraft too vulnerable).

Use of makeshift special weapons, hastily designed and assembled, as with the Toka, in attempts to absorb stocks of old materials.

VII. RAMMING TACTICS AGAINST B–29s

General

In April 1945, after about 6 months of operational experiments, the Army Air Force adopted specific rules for suicide ramming attacks by orthodox fighters against B–29s. These tactics were based on sound scientific research as well as by a study of actual "Combat examples of body attacks" (Figure J).

Tactical Procedure (Figure K)

Preparation.—Japanese pilots were primarily cautioned as to the tactical surprise advantage of making only one approach. They were given a thorough knowledge of the B–29, including flying characteristics, effective angles of attack, and vulnerable points of impact. To facilitate rapid ascent and greater maneuverability, machine guns and other dispensable equipment were removed. A special and detailed ground check was made on oxygen and communications equipment which were considered of vital importance to this type of mission.

Waiting period.—The fighters formed a "protective circumference" around the center of the strategic area in which the attack was expected, and strictly adhered to their assigned positions to avoid confusion. Radio communication was maintained with the ground as well as with the other planes in the patrol sector.

Search and contact.—The entire patrol was to execute a careful search and as soon as the enemy was detected the bombers' axis of flight was determined and the B–29s were approached along that line. Position was to be taken up swiftly; not overlooking the possibility of launching the attack from the clouds, or utilizing the position of the sun. Superiority of altitude was to be immediately gained and maintained.

FIGURE J.—*Combat examples of ramming attacks by Japanese army fighters against USAAF B–29 bombers*

Pilot's name	Unit	A/C type	Direction of attack	Region of collision	Result to B–29	Fighter casualty
Corp Handa	47 fr	Type 2 (Tojo)	Front side	Tail slightly forward	Damaged	Killed.
Sgt. Sawamoto	53 fr	Type 2 (Nick)		Right inboard engine	do	Do.
1st Lt. Shinomiya	244 fr	Type 3 (Tony)	Head on	Near outboard engine	Destroyed	Safe.[1]
Corp. Itagaki	do	do	Above front side	Unknown	Damaged	Parachuted to safety.
Sgt. Yoshida	do	do	Above rear	Right inboard engine	do	Killed.[2]
2d. Lt. Watanabe	53 fr	Type 2 (Nick)	Above front side	Unknown	do	Do.
Maj. Hirose	Meiji air group	Type 4 (Frank)	Unknown	Empennage	do	Do.
Capt. Kawakami	do	Type 1 (Oscar)	Front	Engine	Destroyed	Do.
Sgt. Kuroda and Sgt. Takahashi.	16 fcs	KI–46 (Dinah)	Below right	Empennage	Damaged	One killed; one parachuted to safety.
1st Lt. Shiroda	55 fr	Type 3 (Tony)	Unknown	Tail	Destroyed	Killed.
1st Lt. Urai	56 fr	do	Above front side	Front	Damaged	Do.
Sgt. Takamuko	do	do	do	Rudder	do	Safe.
Sgt. Major Awamura	47 fr	Type 4 (Frank)	Rear	Tail	do	Parachuted to safety.
Sgt. Koman	do	Type 2 (Tojo)		In-board engine	do	Killed.
2d Lt. Tango	244 fr	do	Rear side		Destroyed	Do.
2d Lt. Takayama	do	Type 3 (Tony)	Above rear	Tail	Damaged	Parachuted to safety.
Capt. Kobayashi	do	do	do	do	do	Do.

[1] Plane lost half of left wing. Landed safely.

[2] At time of crash, all but fuselage fell off. Because of damage to parachute, pilot died.

Attack by single fighter.—(1) *The nose attack* was preferred not only because of the amplification of the surprise element, but in view of the lesser bomber fire power from that sector. It was deemed advisable to approach either from a position slightly above and ahead of the bomber close to the line of flight or directly head on. An approach from ahead and below was also considered satisfactory, but in all cases a high degree of mobility was demanded in the event that there was a major degree of deviation by the bomber near the end of the attack.

Tail attacks were to be avoided in view of the long exposure to the heavy fire power. The only exceptions to this rule were allowed when a bomber's guns jammed or when it ran out of ammunition, and where judgment was used in drawing the fire of the turrets.

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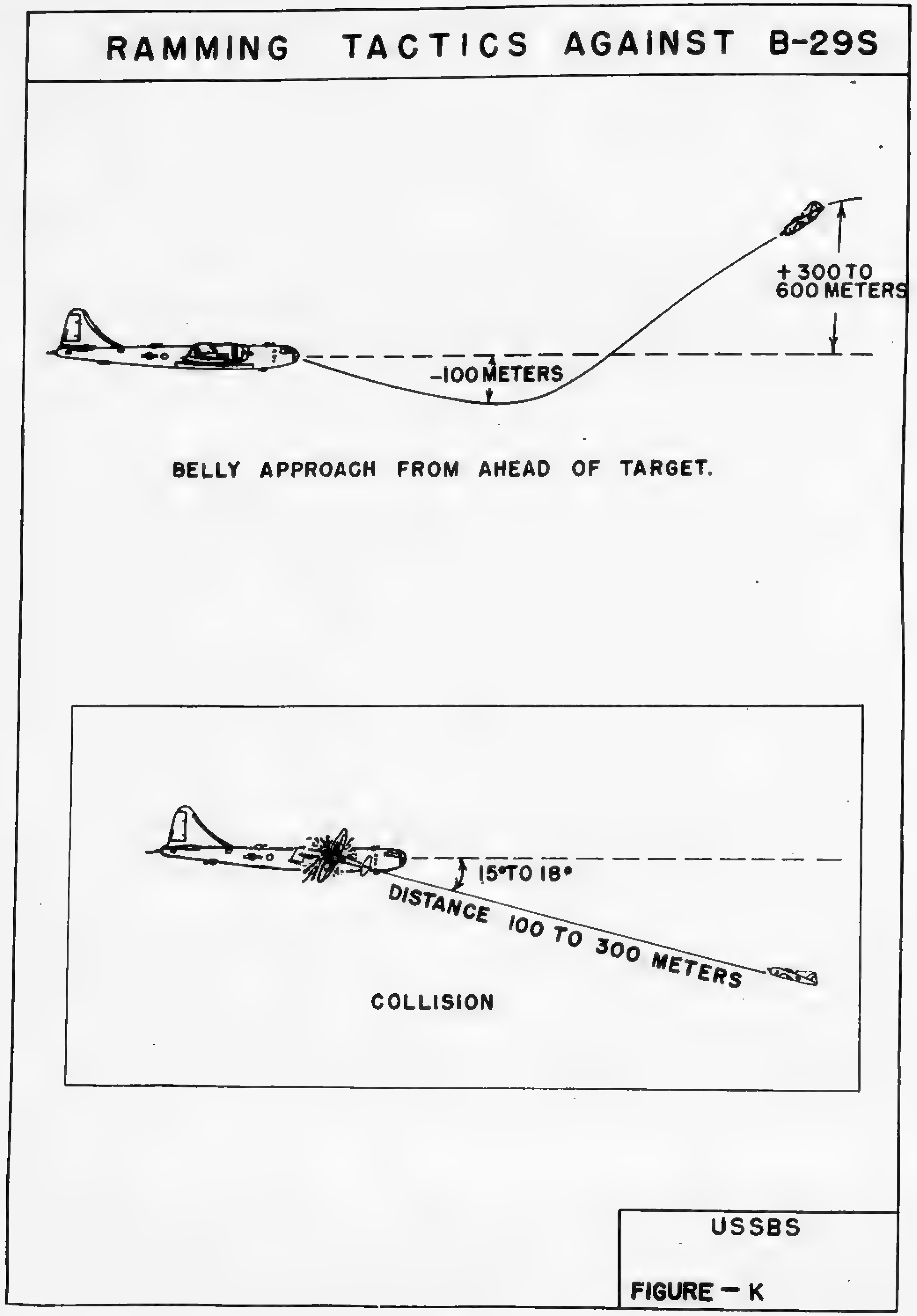


The collision.—In a frontal approach it was believed best to make the attack against the air-tight compartments; in a rear or side approach the empennage was to be selected as the target. During this nose attack it was considered advisable to throttle back in order to gain time. However, upon colliding the action was to take place in one swift movement, and it was deemed desirable to incline the wing toward the vertical in order to increase the probability of a hit. Fighters were repeatedly warned against preliminary approaches which might induce "appropriate and radical evasive action" on the part of the bomber. A recommended angle of attack is shown in figure K.

Mass attacks.—Mass collisions promised the best results, so every effort was made to promote attacks in force. Fighters were instructed to maintain formation during the waiting period. Upon confirmation of the target by the squadron commander, instructions were given to the pilots regarding the commander's decision as to the best approach. Based upon a study of standard United States Antiaircraft Force formations, specific rules were adhered to in target selection in order to prevent conflict. However, in case a single plane unexpectedly encountered the enemy, the pilot was supposed to attack on his own initiative while maintaining radio contact.

Training

During ground training, pilots were drilled on the importance of a successful collision, and constant efforts were made to instill trainees with patriotism. The course of instruction covered enemy capabilities (especially weak points, formations and tactics), plus a thorough knowledge of the fighter pilot's own limitations. Actual flight training in making contact with approaching pseudo attackers was covered in the final phase.

Assessment of Results

An examination of figure J discloses that attacks (prior to the adoption of the above SOP) resulted in 4 B–29s destroyed and 13 damaged. It is evident that even these haphazard attacks, which at first glance seem highly inefficient, were in reality very effective. An analysis reveals the following results attained:

Japanese casualties: Eleven airmen; sixteen fighters destroyed.

American casualties: Forty airmen; four B–29s destroyed.

These statistics do not take into consideration possible additional bomber crew casualties and the probable extensive damage to the targets not destroyed. It is evident that even with orthodox aircraft, proper instruction could raise the standards of proficiency to a high degree, especially when employing mass attacks. Although the target value of a B–29 was only a fraction of that of a surface vessel, there was the compensating factor that a pilot could reattack after a mid-air miss.

Fortunately for the B–29s, the Japanese Air Forces had become relatively impotent by the time the tactical procedure for ramming was being perfected.

VIII. JAP FIGHTERS vs THE B-29

General

During the 9 months of Twentieth Air Force B–29 operations, the fighter opposition never began to approach the intensity of that offered by the Luftwaffe. Furthermore the effectiveness was greatly diminished because of the Japanese interceptor's poor high-altitude performance and lack of heavy armament.

B–29 Operations

The B–29 missions may be divided into three categories:

High altitude precision daylight missions (24 November 1944 to 25 February 1945).—The bombing program of this period limited the B–29s range and target selection. Therefore, the Japanese were able to concentrate their fighters in their defense of these few areas. Throughout this phase, relatively small B–29 forces met their most intense opposition from Japanese interception which showed continual improvement.

Low and medium altitude daylight missions (25 February to 14 August 1945).—The lower-bombing altitude, which increased the B–29 range was coupled with the employment of far greater numbers of B–29s. Thus, the Japanese were no longer able to concentrate their fighters at a few points. The diversion of the Japanese Air Force to the Okinawa campaign, and the employment of B–29 fighter escort further contributed to greatly diminishing Jap fighter attacks.

Night missions.—On 9 March, during the period of unaggressive Japanese fighter activity, night missions were initiated by a force of almost 300 B–29s. Some more effective Japanese night-fighter armament was employed, but the Japanese performance was still below par and handicapped by the increased difficulty of locating and maintaining contact with the B–29s.

Japanese Daylight Fighter Tactics (Conventional Armament)

Attacking out of the sun or clouds was considered relatively unimportant to the Japs in view of their final tendency to standardize on two combat-proven tactics. Both these tactics were extremely difficult for flexible gunners to counter, and embodied maximum incorporation of the surprise element (Figure L).

Straggling members of a loose bomber formation, and isolated B–29s were given first priority on targets. This procedure usually eliminated opposition from heavy defensive formation fire power. Nevertheless, even when attacking a close formation, the surprise element of the frontal attack often precluded an efficient defense.

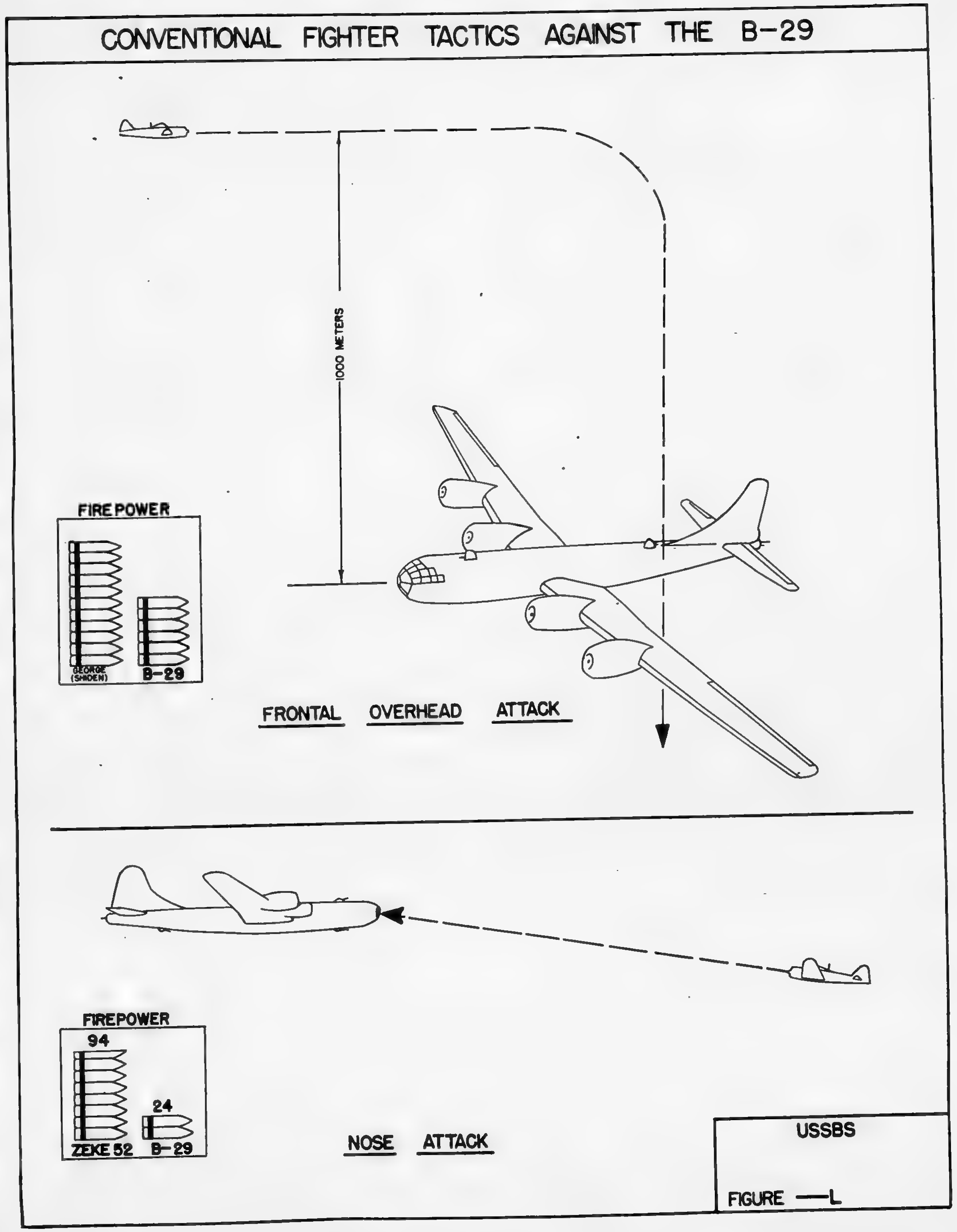
B–29 Weaknesses

The importance and necessity of harmonizing the central fire-control system was given only secondary consideration by the groups and wings because of operational demands on the aircraft and greatly decreased fighter opposition. The over-all consequence was that the majority of central fire-control systems were always improperly harmonized; thereby countering to a great degree the B–29s principal gunnery feature.

The human-surprise element coupled with a slow fire control computer reaction nullified most opposition to the frontal attack.

c. The B–29 crews, assuming the inability of Jap night fighters to locate them, adopted a passive role and gunners were instructed "not to open fire unless fired upon." This procedure resulted in greater comparative safety for the Japanese, especially in view of the Japanese oblique gun installation, and the B–29s night silhouette vulnerability (chapter X and figure V). The night flying B–29B, being equipped with only tail armament, was totally unable to oppose the Japanese oblique gun attacks due to the lack of belly defenses. This lightly armed model B was used to supplement the standard B–29 during night attacks.)

The B–29 was unable to produce any "super" fire power against fighter attacks by the orthodox Japanese day fighter.



Heavy Bomber Defense Requirements

A single B–29 could not hold its own in fire power in 1945 against a long Jap fighter; but a further fire power comparison with the more superior Fw–190 or Me–262 emphasizes this defensive weakness.

In addition to the present B–29 all-angle turret coverage, heavier fire power is immediately essential in the following sectors and with the following priority: First, tail; second, belly; third, nose. The heaviest fire power is required in the tail sector not only in view of the tendency for all attacks to finish up in this zone, but because of the simpler flying and sighting problems offered the attacking fighter. The under defenses are next in importance due to the night-silhouette vulnerability from below and the possibility of a simple no-deflection shot from upward-firing oblique guns. The zone next in importance is the nose, due to the major surprise element; however, the attacker's interception and flying problems are amplified due to the high rate of closure, and such attacks become less practicable with the present increases in air speeds.

The overhead and beam sectors are least vulnerable: Maximum altitudes complicate overhead attacks; and pursuit attacks from these angles will wind up in the tail zone. Parallel oblique-gun attacks from the beam or above are less simple and not as practicable as belly attacks.

The tail sector of the heavy bomber is most urgently in need of increased fire power. The minimum total fire power output should be at least equivalent to the heaviest-armed fighters of World War II (the most efficient aircraft cannon of the war, the German Mk–108, is now in the hands of all major powers and it is not unlikely that guns in this category will be used during the initiation of any conflict in the near future). The vulnerability of American bombers to the Mk–108 has been clearly demonstrated in the European theater, therefore this fire power increase is required for the immediate future, possibly by the modification of existing installations. It should be noted that even the early inferior Japanese fighter fire power output rapidly arose to a point in 1945 where it exceeded United States aircraft fire power (Figure S). Although it was not until late in the war that the Japanese were able to surpass the fire power of our heavy bomber tail defenses, it must be remembered that the Luftwaffe succeeded in doing this two years earlier, in 1943; and even the lightly armed Japanese was earlier able to exceed our fire-power defense by selection of angle of attack (Figures L and V). (The Sam (Reppu), formerly a carrier-based fighter armed with four 20-millimeter cannon, was later experimentally remodeled along interceptor lines with six guns of 30-millimeter caliber.)

The theory of bomber-formation fire-support implies that fire power will be multiplied by inter-aircraft support fire against an attacker. However, in actual practice the inevitable straggling bomber and the adoption of defense-saturating mass fighter tactics nullified this theoretical advantage, and often resulted in one bomber versus one or more fighters.

The accuracy of a gyrostabilized automatic computing gun sight, and radar ranging and tracking are essential to good day and night fire control.

Future trends will undoubtedly necessitate further changes in bomber defense. The additional airspeed and higher altitude will materially decrease the bombers vulnerability, and possibly preclude most nose attacks. However, with the advent of guided missiles (including piloted, remotely controlled, and homing types), the tail sector will remain increasingly vulnerable to attack. The potentially smaller size and lower vulnerability of guided missiles will increase the need for more effective tail defense and necessitate revolutionary counter weapons.

IX. MACHINE GUNS AND CANNON

General

The study of Japanese aircraft armament reveals a drastic failure on their part to standardize on any one particular weapon for each caliber size. The separate development projects carried out by the two services, Army and Navy, have produced an unsurpassed variety of weapons requiring various types of ammunition.

A parallel comparison of American and Japanese machine guns and ammunition types reveals the great extent of this failure to standardize (Figures M and N).

Figure M.—*Aircraft machine guns—Operational types*

Caliber class	United States Air Forces: Army and Navy	Japanese Air Forces: Army or Navy
.30 inch	cal. .30 Browning	Cal. 7.7 millimeter type 89 Japanese A. Cal. 7.7 millimeter type 89 Vickers A. Cal. 7.7 millimeter type 92 Lewis N. Cal. 7.7 millimeter type 97 Vickers N. Cal. 7.92 millimeter type 1 Dreyse-Solothurn MG15 N. Cal. 7.92 millimeter type 98 Dreyse-Solothurn MG15 A. Cal. 7.92 millimeter type 1 Bren A.
.50 inch	cal. .50 Browning	Cal. 12.7 millimeter HO 103 type 1 Browning A. Cal. 13 millimeter type 2 Mauser MG–131 N. Cal. 13.2 millimeter type 3 Browning N.
20 millimeters	cal. 20 millimeter Hispano-Suiza	Cal. 20 millimeters HO-1 and 3 Japanese A. Cal. 20 millimeter Mauser MG–151/20 A. Cal. 20 millimeter HO–5 Browning A. Cal. 20 millimeter type 99 Oerlikon MK-I N. Cal. 20 millimeter type 99 Oerlikon MK-II N.

Derivation of Basic Designs

United States: Browning, Lewis. *Czech-British:* Bren. *German:* Mauser, Dreyse-Solothurn. *United States-British:* Vickers (Maxim). *Italian-Swiss:* Hispano-Suiza. *Swiss:* Oerlikon. A—Army. N—Navy.

Explanatory Notes: Aircraft Machine Guns (Figure M)

This weapon is a development of a light machine gun used by the ground forces. There were two distinct types: the single fed by a flat drum magazine; and the dual, consisting of a right- and left-hand gun mounted on a light tubular frame and fed by two quadrant-shaped magazines.

The mechanism of these weapons is basically the same. However, though the calibers are both 7.7 millimeters, ammunition for one cannot be used in the other. The Navy type 97 uses rimmed ammunition and the Army type 89 uses a semi-rimmed cartridge.

The navy 7.7-millimeter guns are chambered to fire the British .303 ammunition, and are almost exact copies of British models. Limited quantities of captured British ammunition were used.

Despite the identical caliber and common mechanism, no attempt was made to standardize these guns, and the components were not considered interchangeable.

This is a twin-mounted gun, and is sometimes designated the type 100.

These guns both bear a very close resemblance to the United States caliber .50 Browning, but none of the ammunition is interchangeable.

This gun is a very close copy of the German Mg–131. The ammunition is similar to that used by the Germans, but, due to difficulty in perfecting the Luftwaffe's highly efficient electrical synchronization, the standard percussion type primer was employed.

The prototype of these guns was the Japanese Infantry 20 millimeter type 97 antitank rifle. Ammunition is the same for both types but the magazines are not interchangeable.

This weapon was imported in large quantities from Germany and has been found only with German-manufactured ammunition.

This gun is an enlarged model of the U. S.

caliber .50 Browning, and was the first 20 millimeter gun capable of synchronized fire produced by the Japanese. (The United States 20-millimeter aircraft gun was not capable of synchronization.)

There were three models of the Mark I version and all fired the same ammunition. The Mark II was later designed in order to increase the muzzle velocity; this new ammunition had a longer cartridge case but contained the same projectile.

Development 1940–45

Up until 1940 research and development was centered in the rifle caliber class (7.7 millimeters). Aircraft guns were principally limited to adaptations of existing British weapons (Vickers, Lewis, and Bren), with the Navy going as far as to adopt the .303 British ammunition. In 1942, production was under way by both the Army and Navy on copies of the Rheinmetall 7.92 millimeter gun (German Mg–15) following the receipt of specimens purchased from Germany.

As early as 1937, 20-millimeter guns were being manufactured under the guidance of the "Oerlikon" company. Three years later, in 1940, the superiority of this caliber was revealed when they were used as wing guns on the Zero fighter over Hawnkow, during the China Incident. Despite this early operational trial, it was not until late in 1944 that guns in the 20-millimeter or even the caliber .50 class were installed for all-around operational use. This delay can be attributed to the insistence of many pilots to have wing guns removed in order to retain their only performance advantages: maneuverability and climbing speed. Furthermore, the continued unreliability of the Japanese synchronization system prohibited efficient fuselage installations.

After ground firing tests with numerous types, including a trial 25-millimeter gun, vulnerability estimates brought forth the sound conclusion that a gun of at least 30 millimeters was required for an effective percentage of heavy bomber kills. Late in 1943, this theory was verified in combat by a few zeros (equipped with 30-millimeter wing guns) which went into action at Rabaul. With the growing emphasis on antibomber tactics, plans were initiated to develop more efficient types in the heavier, 30-, 37-, and 40-millimeter categories. (Under this program the Navy designed the original and efficient type 5, 30 millimeters; and the Army the revolutionary Ho–301, 40 millimeters.) Upon hearing of the German antibomber successes, steps were taken to purchase quantities of the highly superior Mk–108, 30 millimeters and ammunition. However, the German submarines transferring this material were captured or sunk, and all that ever reached the Japanese Air Forces were two specimens.

During the last year of the war, an attempt was made to follow the steps of the pioneering Luftwaffe, and efforts were applied toward the development of a gun capable of downing a bomber with a single hit. In view of the increasing urgency for standardization, a belated decision was made to have the Army handle all the designing for cannon in this category. The following experimental models were undergoing development when the war ended:

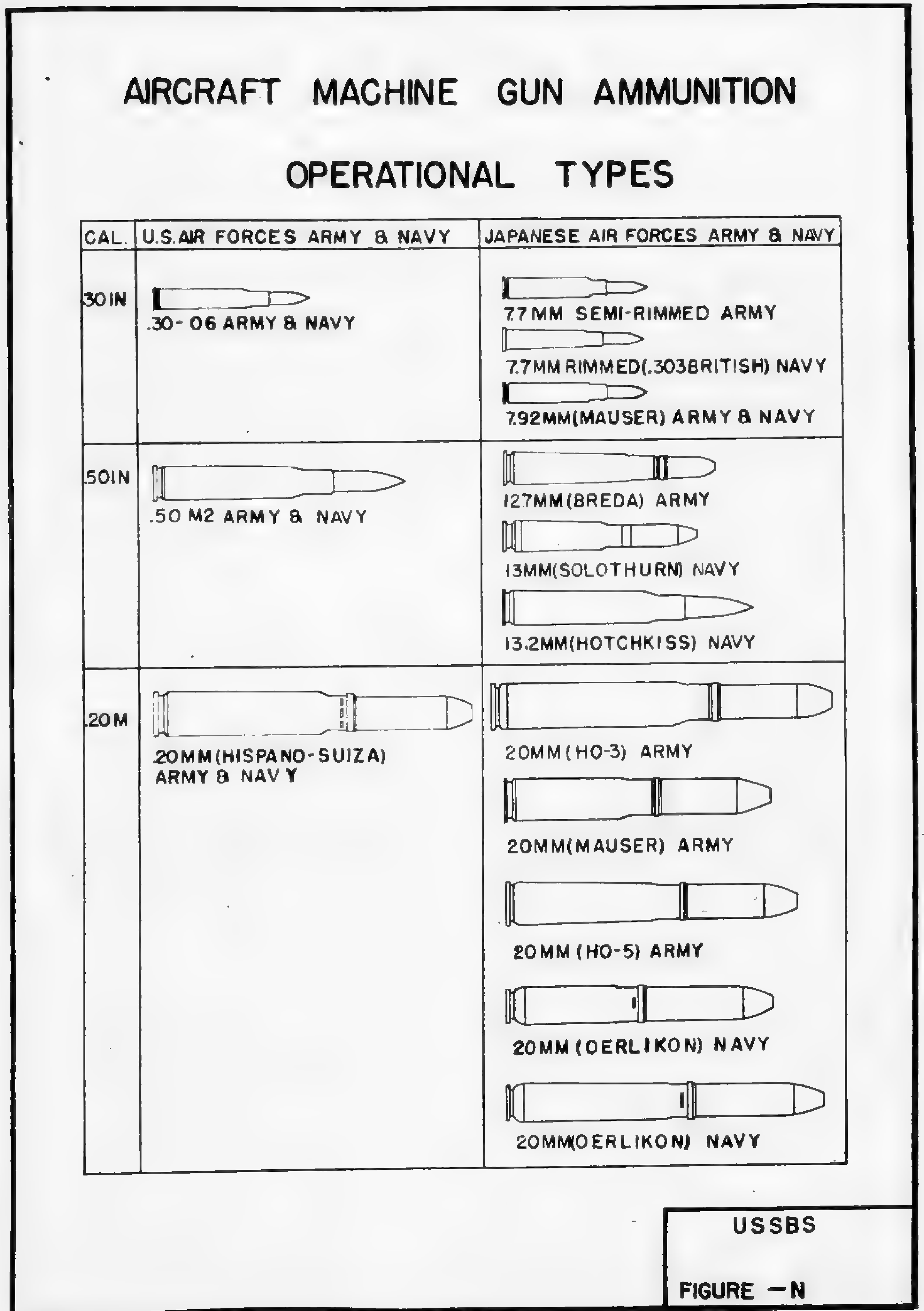
1. Ho–251, 47 millimeters.
2. Ho–401, 57 millimeters.
3. Ho–402, 57 millimeters.
4. Ho–501, 70 millimeters.
5. Ho–505, 75 millimeters.
6. Ho–600, 120 millimeters.

Noteworthy Developments (Figure U)

The "MA" projectile.—The Army developed a very efficient, fuzeless, high explosive incendiary projectile. This ammunition was so simple in design, and proved so efficient in gas tank and fuselage ignition, that it was undergoing adoption by the Navy. The research and development program formulated five calibers in the following sequence:

1. 7.7 millimeters (Ma–101).
2. 12.7 millimeters (Ma–102) for use against B–17s and B–24s.
3. 20 millimeters (Ma–202) for use against B–17s and B–24s.
4. 37 millimeters (Ma–351) for use against B–29s.
5. 30 millimeters (Ma–301) for general antibomber use.

It is interesting to note that complete specimens of American bombers were unavailable in Japan in September of 1943, during the Ma ammunition firing tests. In view of this the Army air technical laboratory undertook the construction of full-size models of B–17s and B–24s exactly to United States specifications. (Tests with the 13-millimeter Ma against the B–17 model disclosed



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great difficulty in effecting penetration of wing tanks directly from above as opposed to easy penetration from the front and rear.) Resultant Japanese theoretical estimates of hits required to down a heavy bomber (B–17 or B–24) were as follows:

Ground test results:

	Combat condition estimates (Rounds)
Ma–102 (13 millimeters) =5–6 rounds	20
Ma–202 (20 millimeters) =2–3 rounds	10

Due to the fact that the nonvulnerable target areas were not given full consideration (the incendiary effect was generally limited to gas tanks) coupled with the lack of accurate combat assessments (the Japanese did not carry gun cameras in operations) the estimates were somewhat optimistic. Nevertheless, in the Ma the Japanese had an efficient fuzeless projectile, simple to manufacture, and with excellent incendiary properties.

The Ho–301: 40-millimeter cannon.—This revolutionary Japanese development showed great promise. The ammunition for this cannon is of a type not previously used in automatic weapons. The propelling charge is contained in a cavity in the rear of the projectile and therefore no cartridge case is required. The entire cartridge assembly, including the ordinary percussion-type primer is fired from the muzzle. Twelve exhaust ports in the base plate permit the expanding gases to escape and drive the projectile forward. However, this is definitely not a rocket, as the quick-burning propellant is consumed before leaving the barrel. (Figure U.)

The comparatively low velocity of 220 meters per second (722 feet per second) was no great handicap in the light of current antibomber tactics. The cannon was similar to the orthodox Oerlikon design, but was a very light weapon for its caliber, weighing only 40 kilograms (88 pounds). The unusual type of ammunition permitted simple gun construction and efficient operation in view of the following advantages:

The weight of one round was relatively light (only slightly above that of the 30-millimeter Ho-155) and of comparatively small dimensions. This permitted carrying a large number of rounds per gun.

The problems of extraction and ejection of empty cases was entirely eliminated. This not only permitted a simpler mechanism but, furthermore, showed promise of development into extremely high rates of fire.

FIGURE P.—*Characteristics of Japanese Army and Navy Aircraft Guns*

Caliber	Type No.	Overall length	Barrel length	Weight	Muzzle velocity	Rate of fire	Army, navy
Millimeters		*Inches*	*Inches*	*Pounds*	*Feet per second*	*Rounds per minute*	
7.7	89 flex	42½	25	20	2,657	700X2	A
7.7	89 fixed	40½	29	28	2,690	950	A
7.7	92	39	26½	18½	2,500	600	N
7.7	97	40½	28½	28	2,460	800	N
7.92	1 flex	42½	23½	15	2,460	1,000	N
7.92	98 fixed	43	23½	22	2,460	1,000	A
7.92	98 flex	42½	23½	16	2,460	1,100	A
7.92	1 flex	41½	23½	37	2,460	1,100X2	A
12.7	1	50	31½	51	2,560	900	A
13	2	46	21½	38½	2,460	900	N
13.2	3	60	35½	60½	2,625	850	N
20	HO 1&3	55	35½	81½	2,460	800	A
20	MG 151/20	69½	45	93	2,500	800	A
20	HO 5	57	35½	77	2,625	700	A
20	99 Mk I	52½	32	59½	1,970	550	N
20	99 Mk II	73	49	85	2,495	480/750	N
30	2	82	53	112½	2,329	420	N
30	5	82	56½	156½	2,526	530	N
37	HO203	59	31½	176½	1,870	100	A
40	HO301	59	31½	88	722	400	A

Characteristics of United States Army and Navy Aircraft Guns

Caliber (millimeters)	Type	Over-all length	Barrel length	Weight	Muzzle velocity	Rate of fire
		Inches	*Inches*	*Pounds*	*Feet per second*	*Rounds per minute*
7.6 (.30″)	Browning	39½	24	20	2,715	1,250
12.7 (.50″)	Browning	56	36	61	2,950	750
20	Hispano	94½	67½	102	2,950	600
37	M–10	89½	65	231	2,000	165

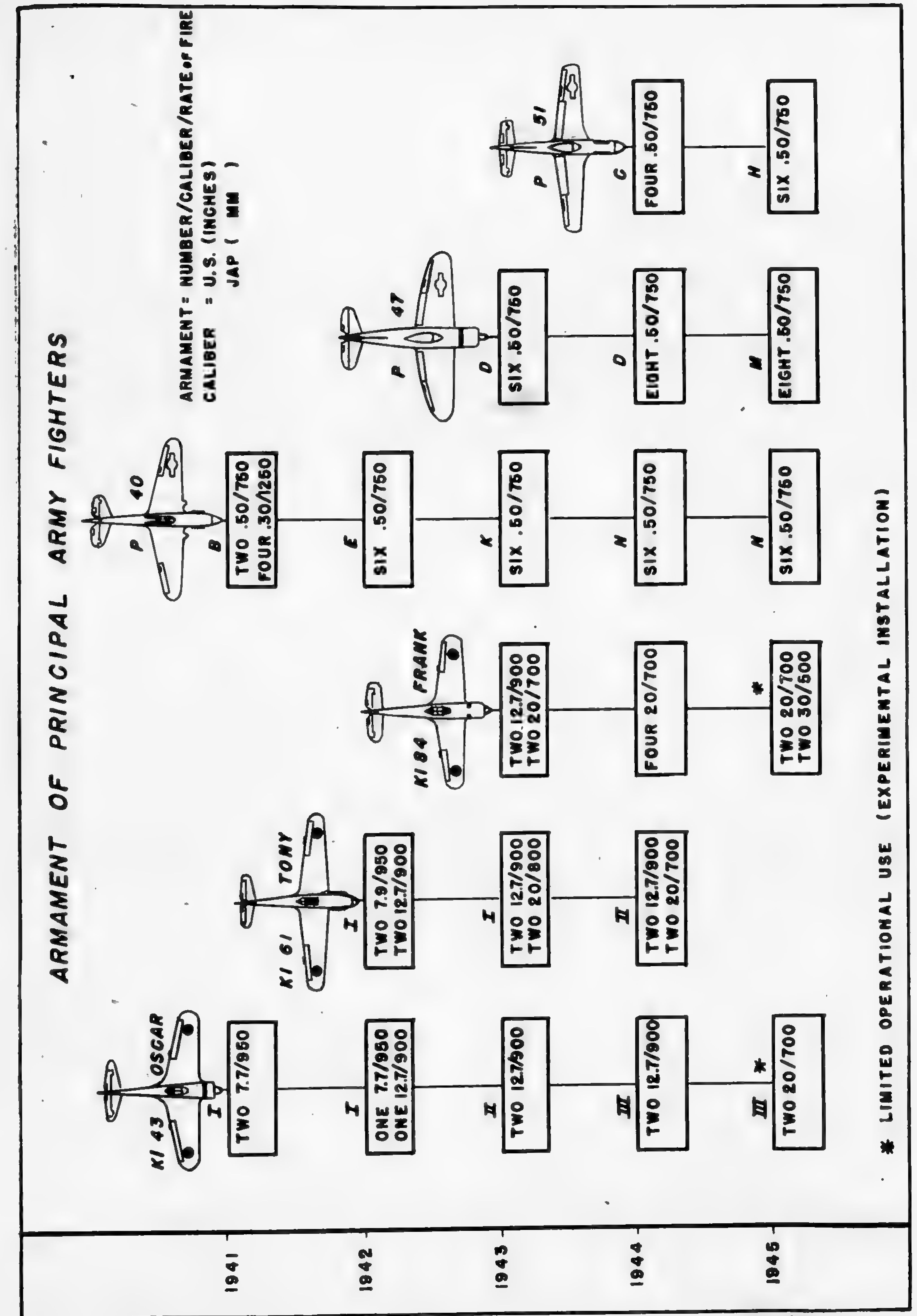


FIGURE — Q

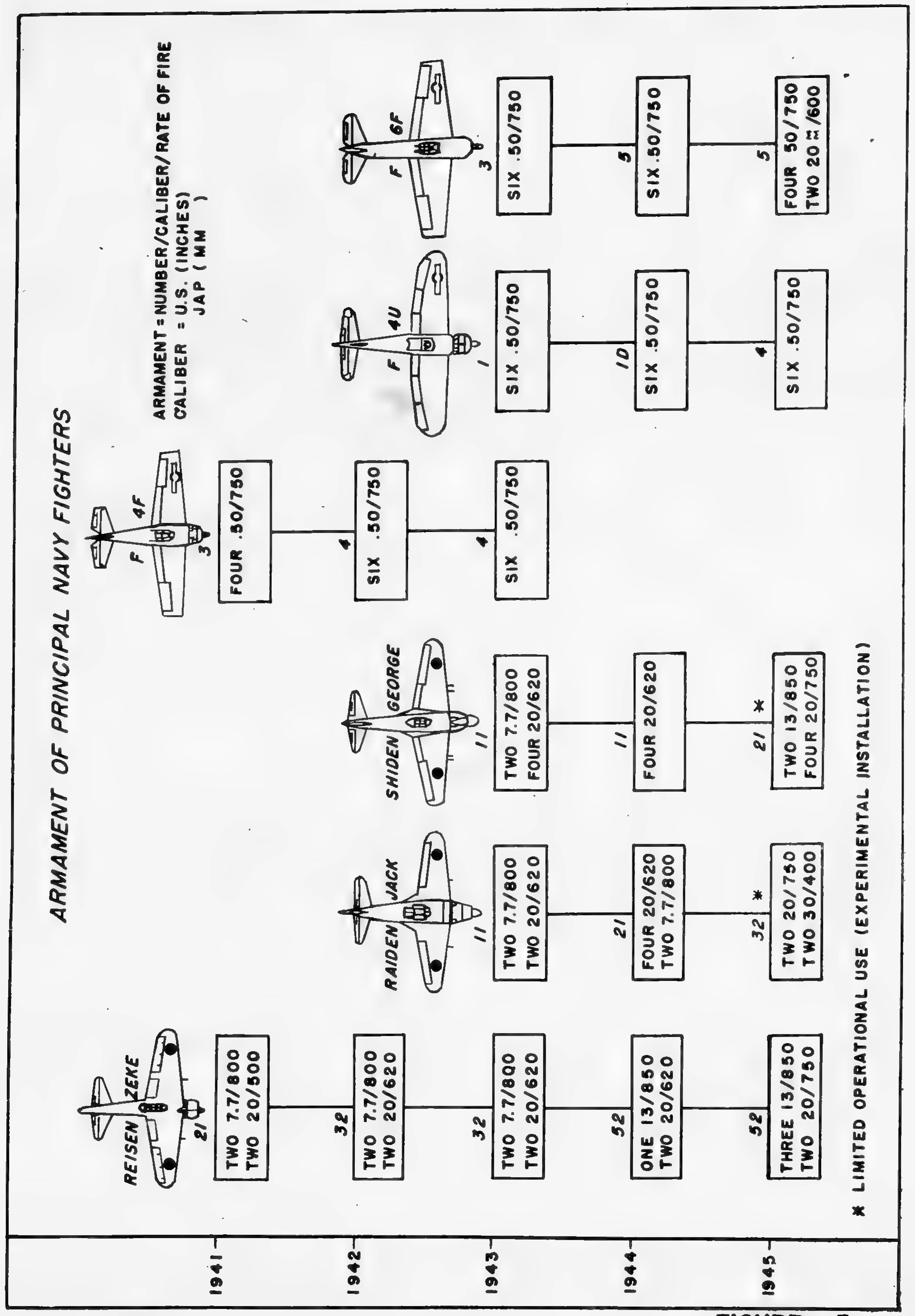


FIGURE - R

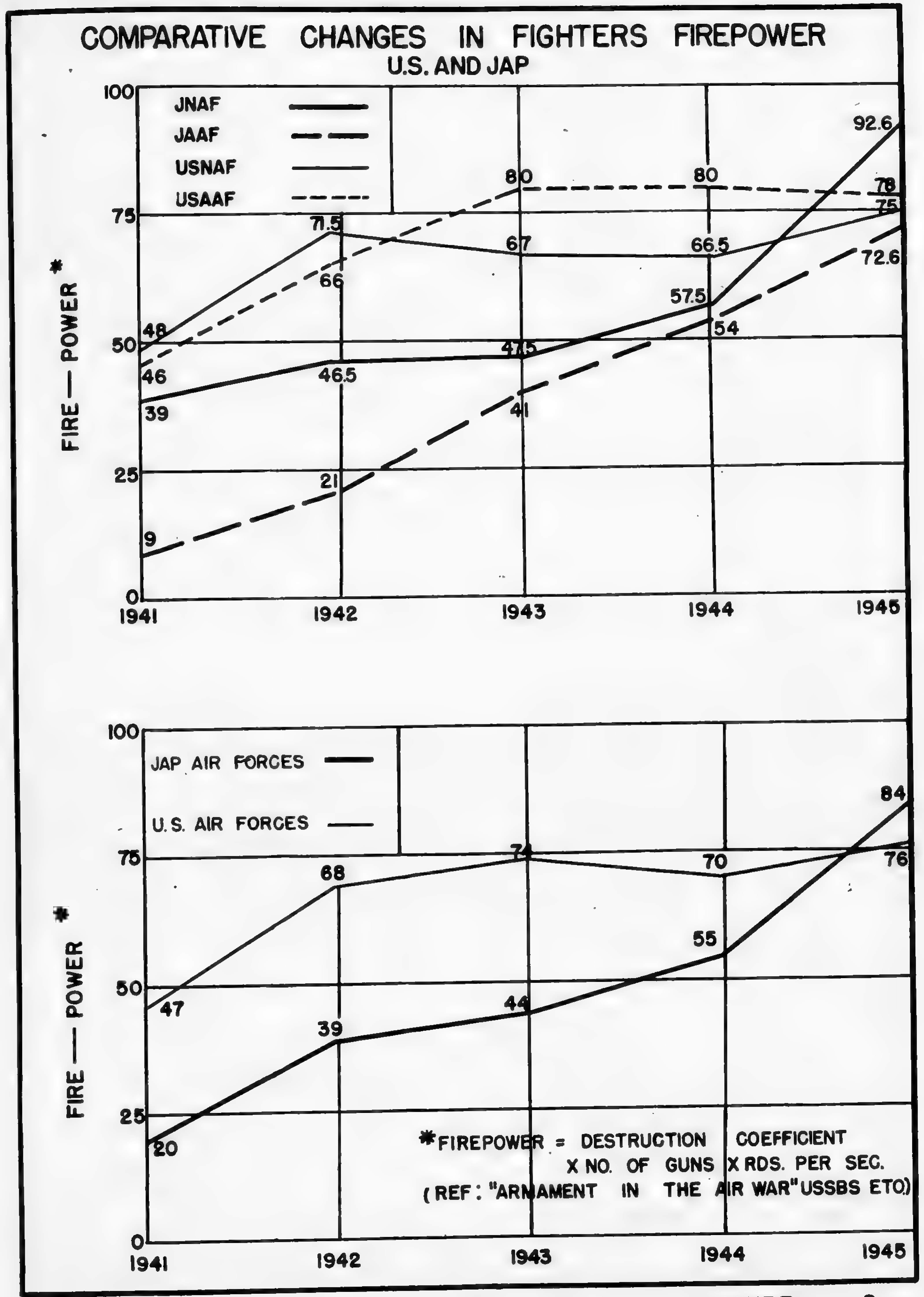
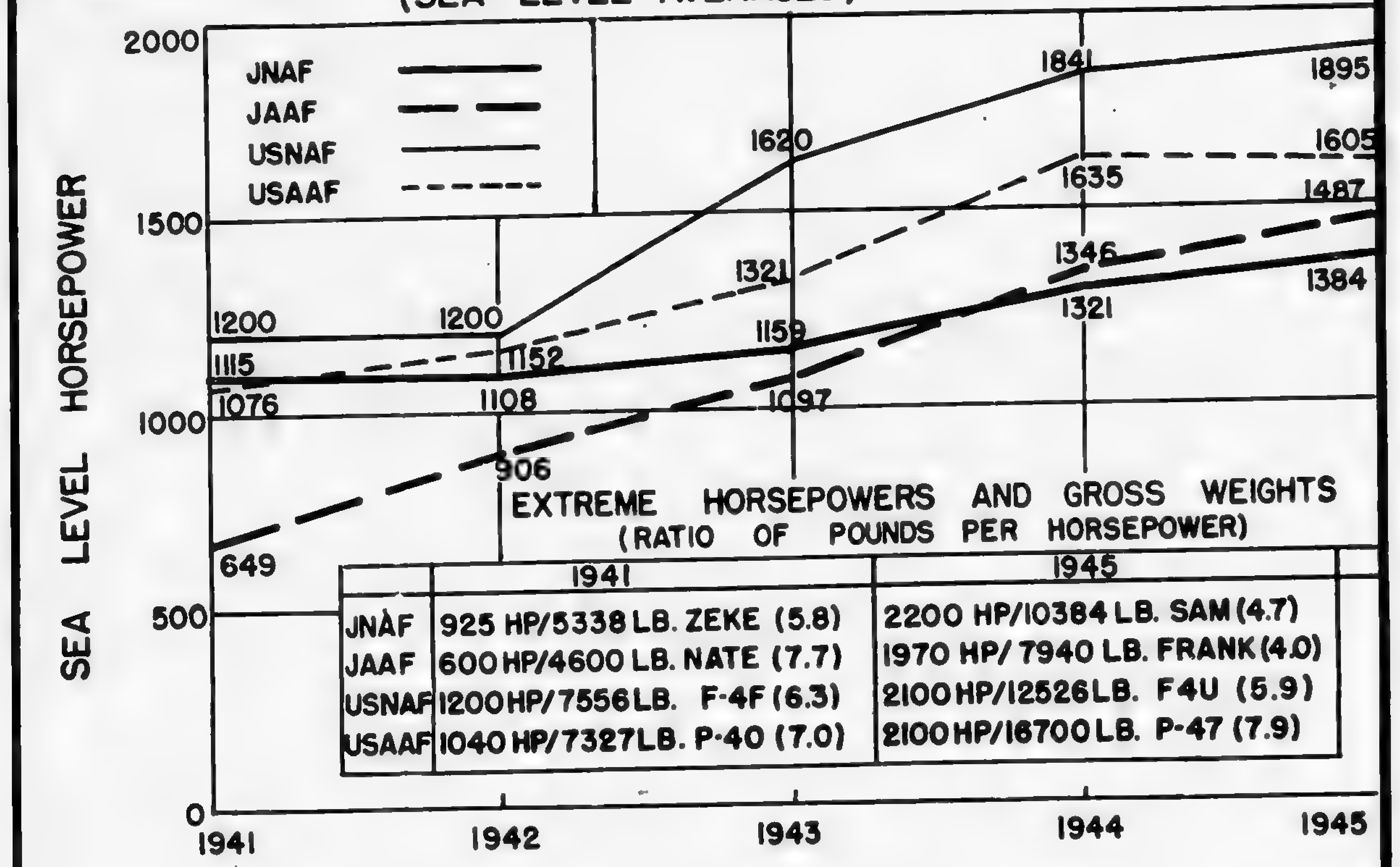


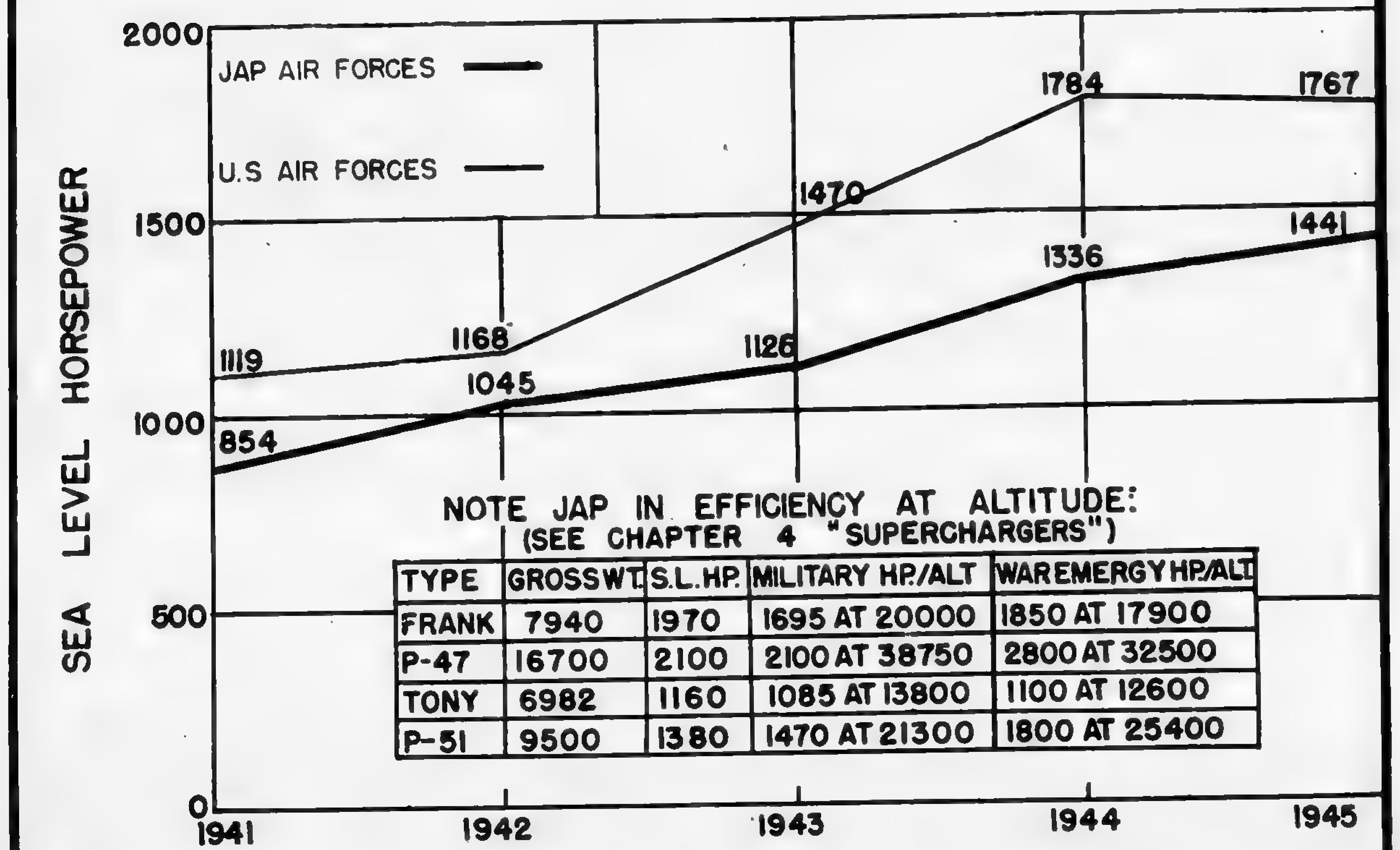
FIGURE — S

COMPARATIVE CHANGES IN FIGHTER HORSEPOWER (U.S. AND JAP)
(SEA LEVEL AVERAGES)



EXTREME HORSEPOWERS AND GROSS WEIGHTS
(RATIO OF POUNDS PER HORSEPOWER)

	1941	1945
JNAF	925 HP/5338 LB. ZEKE (5.8)	2200 HP/10384 LB. SAM (4.7)
JAAF	600 HP/4600 LB. NATE (7.7)	1970 HP/7940 LB. FRANK (4.0)
USNAF	1200 HP/7556 LB. F-4F (6.3)	2100 HP/12526 LB. F4U (5.9)
USAAF	1040 HP/7327 LB. P-40 (7.0)	2100 HP/16700 LB. P-47 (7.9)



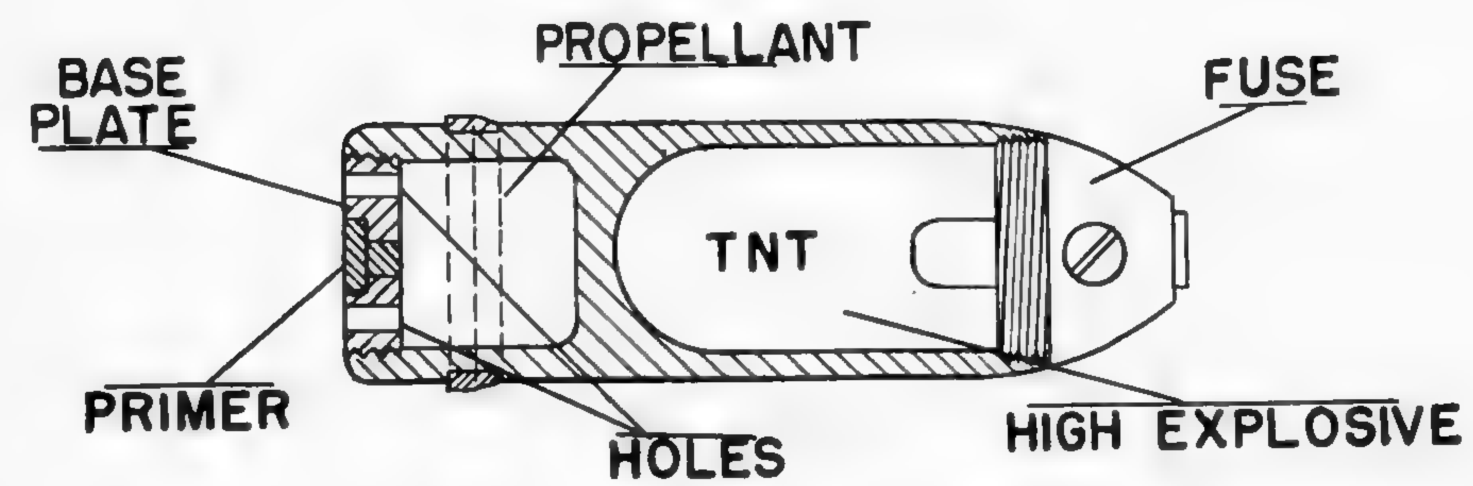
NOTE JAP IN EFFICIENCY AT ALTITUDE:
(SEE CHAPTER 4 "SUPERCHARGERS")

TYPE	GROSS WT.	S.L. HP.	MILITARY HP./ALT	WAR EMERGY HP./ALT
FRANK	7940	1970	1695 AT 20000	1850 AT 17900
P-47	16700	2100	2100 AT 38750	2800 AT 32500
TONY	6982	1160	1085 AT 13800	1100 AT 12600
P-51	9500	1380	1470 AT 21300	1800 AT 25400

FIGURE — T

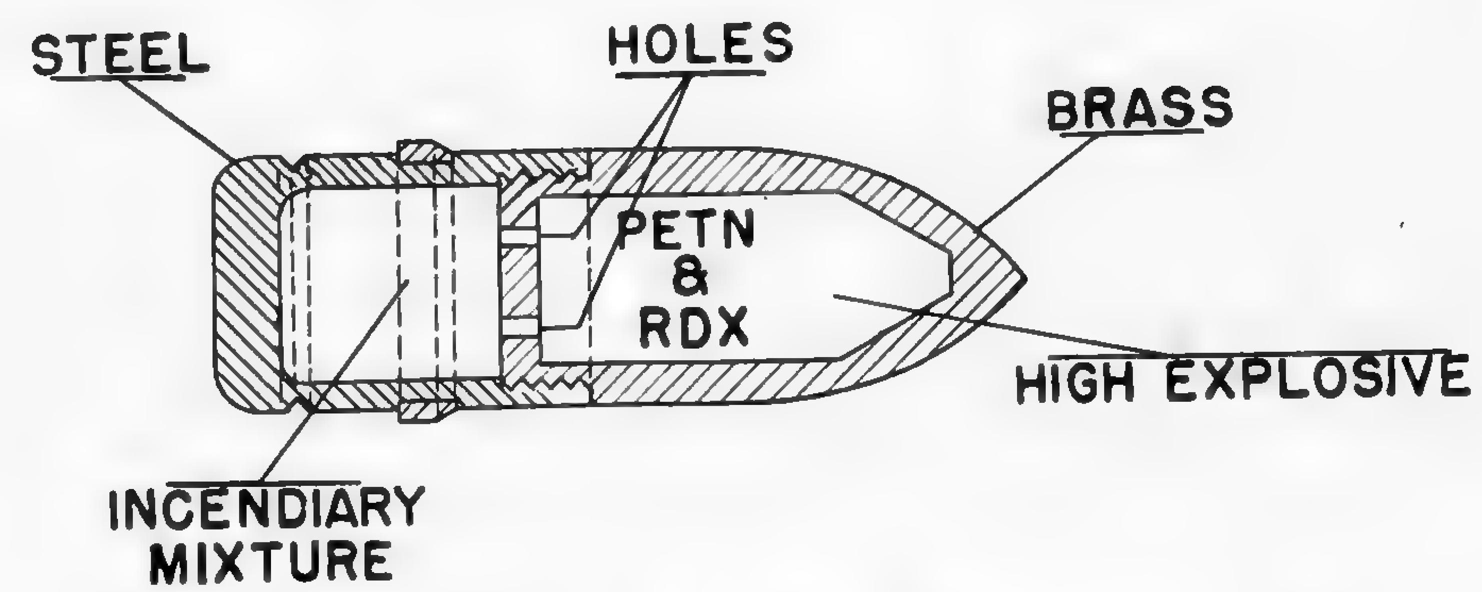
NOTEWORTHY AMMUNITION DEVELOPMENTS

HO-301 — 40 MM H.E.



IN THE HO-301 CANNON THE HEAD OF THE BOLT IS MACHINED AS A PISTON WHICH CLOSES THE BREECH UPON THE FORWARD STROKE.

"MA" FUSELESS H.E. / I



THE FUSELESS MA WAS PRODUCED IN THE FOLLOWING CALIBERS.

7.7 MM (MA 101)
12.7 MM (MA 102)
20.0 MM (MA 202)
30.0 MM (MA 301)
37.0 MM (MA 351)

USSBS

FIGURE — U

X. OFFSET-FIRING FIGHTER ARMAMENT

General

Paralleling the successful Luftwaffe practice, both the Army and Navy fighters made operational use of the highly advantageous inclined-fixed guns. Though not reaching the scientific perfection of the German "magic-eye" automatic firing weapons, the Nipponese added variety to the installations and broadened the tactical application. Though principally used on night fighters, these offset guns neutralized the value of United States flexible gunnery methods (position firing) as well as the automatic compensation of the K–13 variety of gun sight. Army installations were restricted to the upward-firing type, and, in this category, both Army and Navy gave preference to a 30° fore-upward angle, supplemented by a few 70° installations (Figure V).

Army Installations

Ki–45.—Two 30° upward inclined Ho–5 20-millimeter guns, in addition to the following standard mounts; one Ho–203 37-millimeter cannon in fuselage and one type 98 7.92-millimeter dorsal mount (first employed September 1943).

Ki–46.—One 70° upward inclined Ho–204 37-millimeter cannon. (Although originally planned as a reconnaissance type, this proved to have such superior high-altitude performance that in August 1944 it was converted to a fighter pending the appearance of a true high-altitude fighter.)

Same as above in addition to the two standard fuselage-mounted guns, Ho–5 20-millimeters (1945).

Ki–84.—Three upward inclined Ho–5 20-millimeter guns, in addition to the two standard mounted Ho–5's in the wings (experimental, 1945).

Ki–102.—Two upward inclined Ho–5 20-millimeter guns, in addition to the two standard fuselage-mounted Ho–155 30-millimeter cannon.

Navy Installations

Gekko (Irving 11) Fighter.—Two 30° upward inclined plus two 30° downward inclined type 99 20 millimeter guns.

Ginka (Frances).—Four type 99 20 millimeter forward firing guns inclined upwards at 30° (1942).

Seventeen type 99 20-millimeter guns in the bomb bay; 12 firing forward; 5 rearward, and all downward at an inclined angle (experimental).

Twelve type 99 20 millimeter guns in bomb bay, inclined forward to fire in a concentrated cone (experimental).

Raiden (Jack 32).—Two type 99 20 millimeter guns inclined at 30° fore-upward, in addition to the standard two 20 millimeter wing guns.

Suisei (Judy 12).—One type 99 20 millimeter gun inclined fore-upwards, in addition to the two standard 7.7 millimeter wing guns.

Reisen (Zeke).—One type 99 20 millimeter gun inclined at 30° fore-upwards, in addition to the two standard 20 millimeter wing guns.

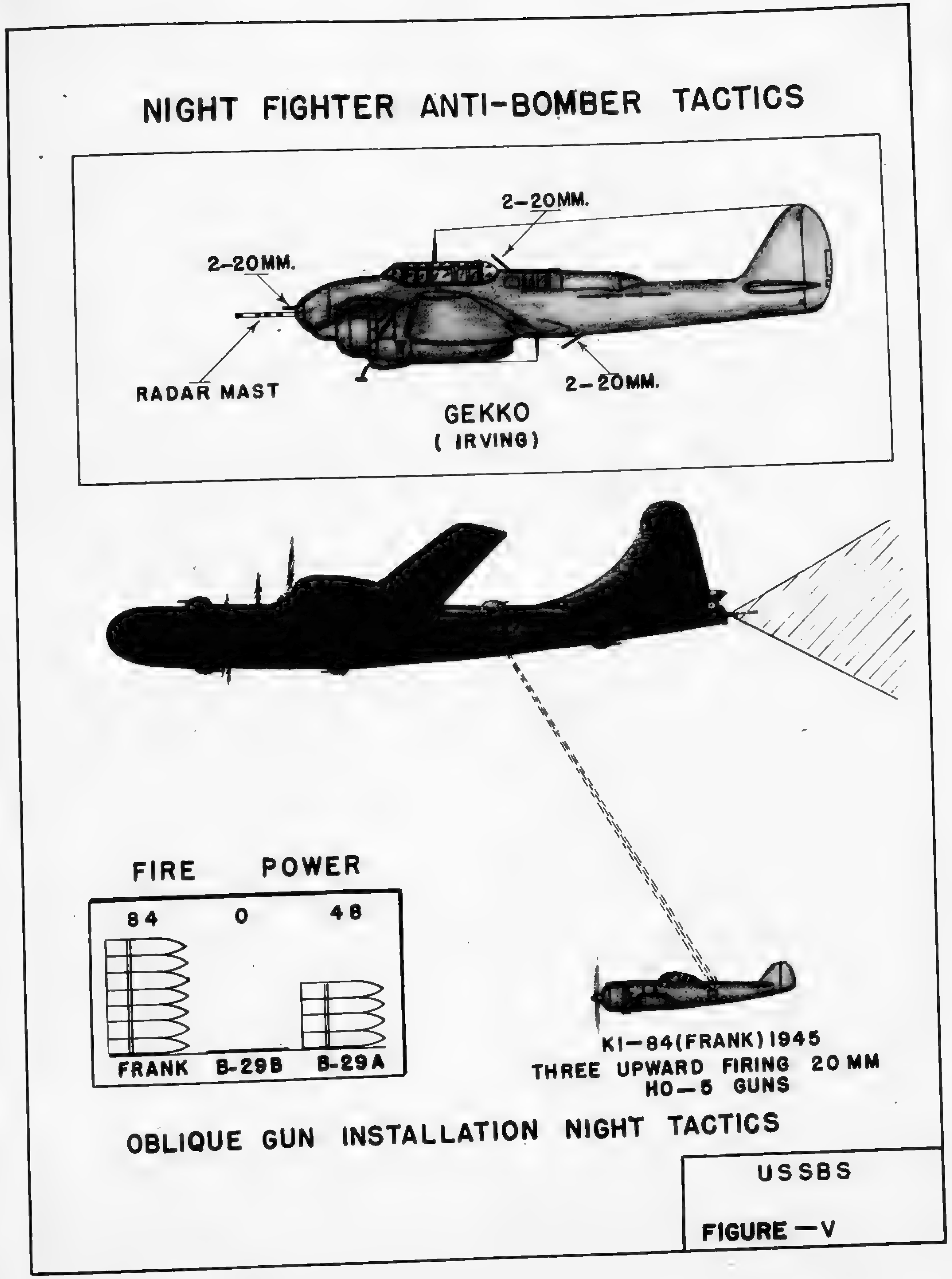
Tenrai.—Two type 99 20 millimeter guns, plus two type 2 13 millimeter guns, all inclined fore-upwards (1945).

Tactics

Antibomber.—The Gekko was used operationally with upward, downward and sideward guns, but battle experience proved that the upward-firing installations were most effective. The Gekko was successfully employed against B–29's and heavy bombers (Figure V). Future plans were centered on wider use of the 30 millimeter machine cannon in inclined mounts.

Airdrome attacks.—Thirty Ginka's with the 17 20 millimeter guns in a downward inclined installation, were in preparation to be staged through Minami to attack B–29 bases in the Marianas and thence to land at Truk. The Navy believes that one pass could wipe out all the B–29's arranged alongside the runway, but the untimely termination of the war put an end to this scheme.

Antilanding craft.—The Ginka with the 12-gun downward installation was designed to discharge a concentrated cone of fire to sweep landing craft approaching a beach head.



XI. SPECIALIZED BOMBS AND BOMBING

Air-to-Air Bombing

a. General.—Much attention was directed toward air-to-air technique, including free falling bombs, cable bombs, and parachute bombs. These very extensive developments were, however, limited in operational use by the poor high-altitude performance of Japanese aircraft.

Theory of free air-to-air bombing.—Research in 1941 by General Masaki resulted in the following sound conclusions:

(1) Only the parallel-course approach would be effective when attacking single aircraft or small units.

(2) Frontal attacks must be limited in use to large formations.

(3) Oblique attacks would be relatively inaccurate.

(4) The choice of time or impact fuze would depend primarily on:

(*a*) Probable error in time of the time fuze;

(*b*) Effective radius of bomb burst.

Ordinary demolition bomb with time fuze.—In 1942 and 1943 the time fuzed demolition bomb was used experimentally. This was employed in a manner similar to the basic Luftwaffe operational technique; whereby the fighter flew a parallel course, and released the single bomb from a height corresponding to the time-fuze setting.

Multiple scattering bombs (Figure W).—The first Army developments in multiple air-to-air missiles were the scattering "baby bombs" which were produced experimentally in 1941 and 1942. The To–3 was primarily for aerial targets, but the principal purpose of other small grenade like objects was to destroy parked aircraft in attacks upon airfields. These could be scattered in clusters of 30 to 40, or individually released in train from auxiliary bomb racks carried under the wings. The To–3 clustered together nose-to-tail in such manner that the arming vane could revolve only after break-up of the cluster.

Evolving from the scattering bomb, the Ta bomb was developed for use against aerial targets. The Ta was a 40 millimeter hollow charge streamlined bomb weighing one-third of a kilogram (0.74 pound) These missiles were released, over bombers, in clusters of 30 or 76 (30 and 50 kilogram [66 and 110 pounds] cluster weight). Japanese Army reports indicate that these bombs brought down several U. S. Antiaircraft Force heavy bombers in the South Pacific, being especially effective against large close formations.

From a theoretical standpoint the tail attack should prove most effective in employing the Ta bomb. However, fighters were reluctant to approach too close to the tail defenses without a 1,000 meter (3281 ft.) advantage in altitude, and such a procedure without a special sight would be futile. The Ta was therefore first used operationally in 1943, with a frontal diving attack employed in view of the lessened danger to the attacking fighter.

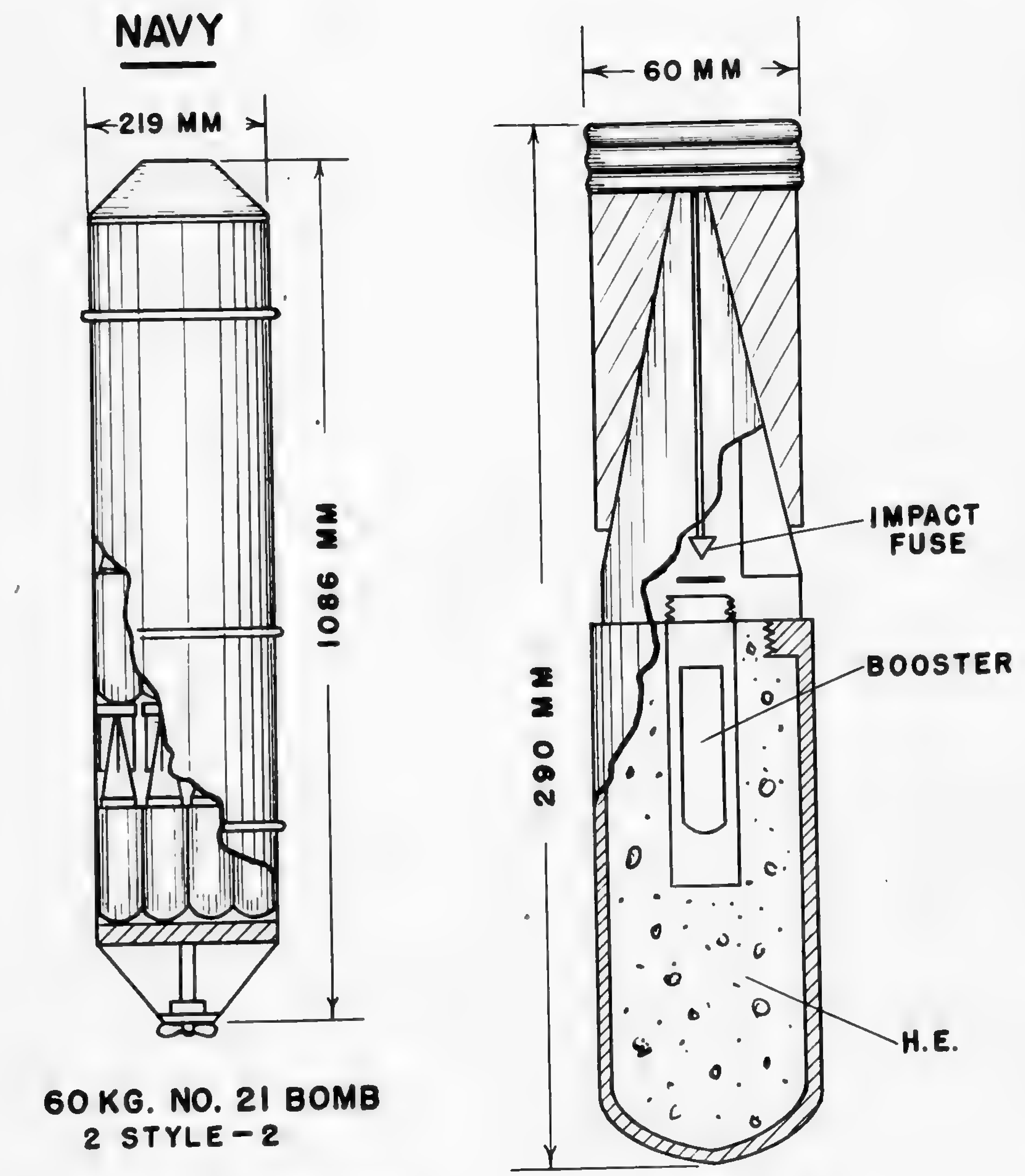
The fronfal diving attack procedure is illustrated in Figure X. The success of this technique was based on a set of tables; precalculated "direct aiming" angles for various altitudes and target speeds. A gun sight was used and the bomb was released at a height H from the release angle MTC. If MTC was the "direct aiming" angle given in the bombing tables, then the time of fall MBC was equal to the time of flight of distance TC, and the bomb will hit the target. If the pilot found difficulty in realizing the "direct aiming" angle, he could make last minute adjustments by using a supplementary correction table.

An alternate method of employing a front horizontal attack was suggested (Figure X). Here the fighter needed only to adjust his relative height. The bomb was released when the target wing span filled a preset reticle width. However, the desire of the fighter to retain freedom of maneuver precluded the use of this simpler method.

Just prior to the armistice, experimental employment of oblique tail attacks were begun against B–29s. This technique remained unperfected when the war ended.

The Navy counterpart of the Ta bomb was a heavier, 1 kilogram (2.205 pounds) hollow-charge

AIR-TO-AIR SCATTERING BOMBS



60 KG. NO. 21 BOMB
2 STYLE–2

(CYLINDRICAL CONTAINER HOUSES 36 BABY BOMBS)

BABY BOMB

USSBS

FIGURE — W

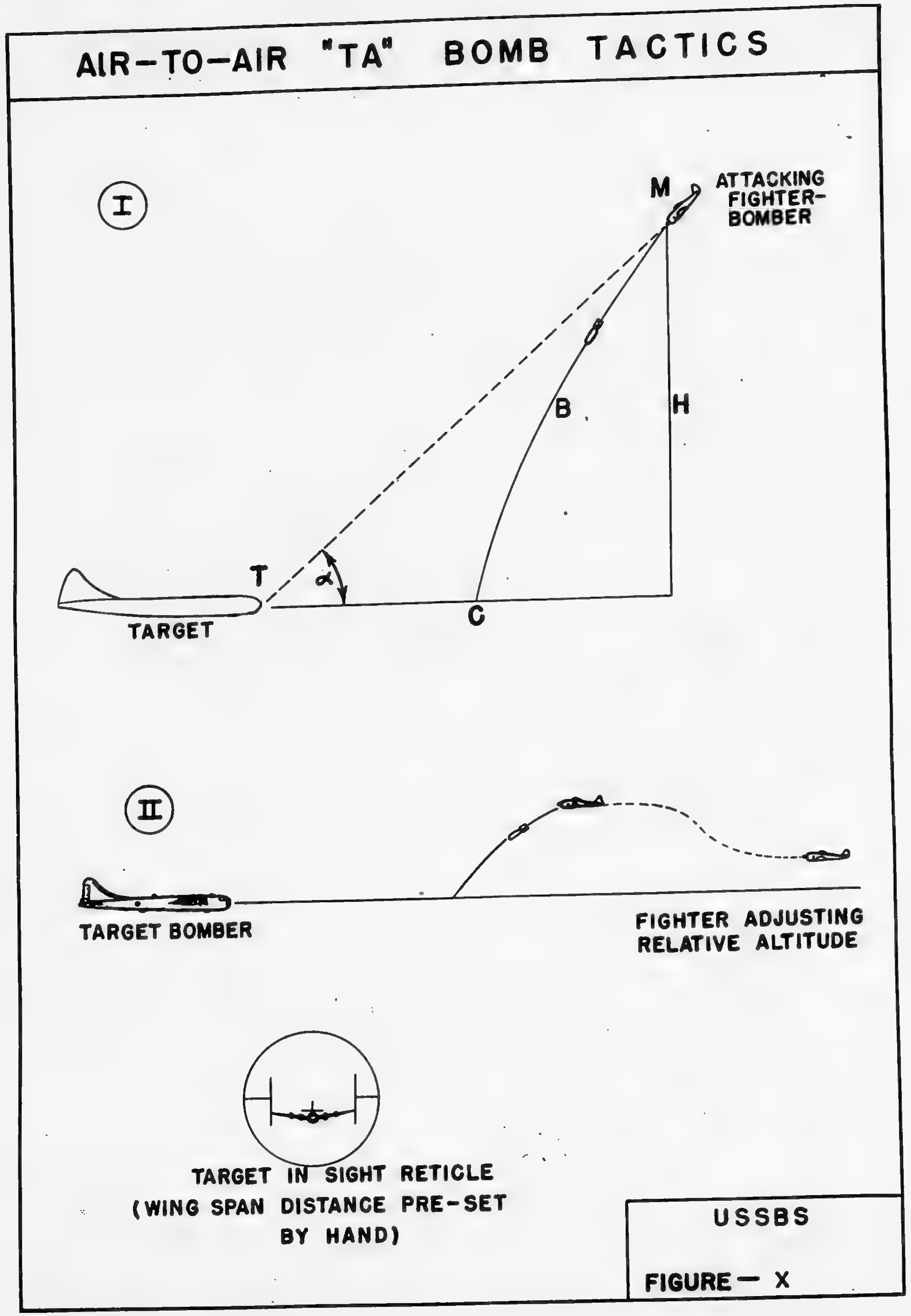


FIGURE — X

baby-bomb, the type 2 No. 6 Mk–21 model I, which was released in clusters of 40. Like the Army Ta, it had an aerial burst fuze which opened the container shortly after release. The hollow-charge, armor-piercing nose, was later considered by the Navy as superfluous against aircraft, and was soon superseded by a more streamlined type which had a solid black-powder nose charge. The final standard, model 2, container housed 36 bombs and weighted a total of 49 kilograms (108 pounds).

Ro-Ta grenade rocket.—To eliminate the need for essential superior altitude on the part of the attacker when employing the Ta bomb, the Ro-Ta was developed in 1945. In this weapon 38 Ta bombs were propelled into the formation, in a rocked-accelerated container. The forward portion of the Ro-Ta contained the Ta bombs plus a time-fuzed expulsion charge which scattered the bombs. Superior height was no longer needed by the attacking fighter who could now fire from a level or low position into the bomber stream. The termination of the war, however, precluded the final development of this excellent weapon.

The Ta–105.—As numerous large American ships had been damaged by Kamikaze attack, it was believed that at the next landing (expected at Kyushu or Honshu) the Allies would employ larger numbers of smaller landing craft. To counter such tactics, the Ta–105, a 100-millimeter version of the original Ta bomb was developed.

The bomb container housed 21 of these Ta–105s. Like the smaller Ta, the outer case opened after release from the aircraft and the baby bombs scattered. Aside from the variation in dimension, the type 105 differed principally from the original Ta in having large folding tail vanes. The Ta–105's hollow charge would be effective against both armored landing craft and tanks, as it was capable of perforating a steel plate 140 millimeters thick.

Incendiary air-to-air bombs (Figure Z).—In contrast to the Army's specializing exclusively in the high-explosive variety of bomb in operations against Allied heavy bombers, the Navy concentrated almost solely on the incendiary type. The mysterious "Balls of Fire" phenomenon was the explosion of the Navy's aerial burst incendiary shrapnel bomb, known to the Japs as the Sango, but later nicknamed the "Fireball" because of American newspaper accounts. There were three sizes, 32 kilogram (70.6 pound), 53 kilogram (117 pound), and 250 kilogram (551 pound), but the one most commonly used against the B–29s was the 32 kilogram (70.6 pound) model, designated No. 3 of the type 99 Mr–3 variety. This bomb carried a bursting charge of shimose (picric acid) and 198 phosphorus-filled steel pellets. The bomb was built with bent tail fins to impart a spin and increase the accuracy.

Parachute Bombing

In 1935 the To–2 parachute bomb was developed for antibomber use, and in 1937 Captain Saito (pilot) developed the tactics illustrated in Figure Y.

The To–2 was a 1.8 kilogram (4 pound) bomb, usually carried in clusters of 10. After release, each bomb freed its individual silk parachute from which it became suspended by a steel cable. For greater depth, 2 sizes of parachutes were used, in order to give 2 rates of falling speed. The total weight of one 10 bomb cluster was only 50 kilograms (110 pounds) thereby allowing as many as 40 bombs to be carried by one single engine fighter. Dropped in the path of a bomber formation, the probability of a strike was good, and a single hit was capable of downing a heavy bomber. The bomber upon striking the cable caused the bomb to swing under the aircraft and explode upon impact of the "all-ways" fuze. Direct hits though less remote would, of course, give instantaneous detonation.

In Saito's recommended procedure the lead fighters continue straight ahead while the wing aircraft fly off to the beam, all dropping their To bombs in the path of the bombers.

This was potentially an excellent weapon, but three reasons precluded its standardization:

The bomb suspension cable, developed in 1937, when aircraft had relatively low speeds, would sever upon contact with modern aircraft.

Further To–2 development was stymied by the great repute of the Ta bomb.

Japanese high-altitude performance was still below par.

Cable Bombing (Figure AA)

The proposed Japanese antiaircraft force tactics for cable bombing were not unlike the Luftwaffe's operational trials, in that the demolition charge was similarly suspended from a 1,000-meter (3,281 feet) long steel cable and dragged through the bomber formation. In both cases the impact-fuzed bomb was lowered by a high-altitude

PARACHUTE BOMBING TACTICS

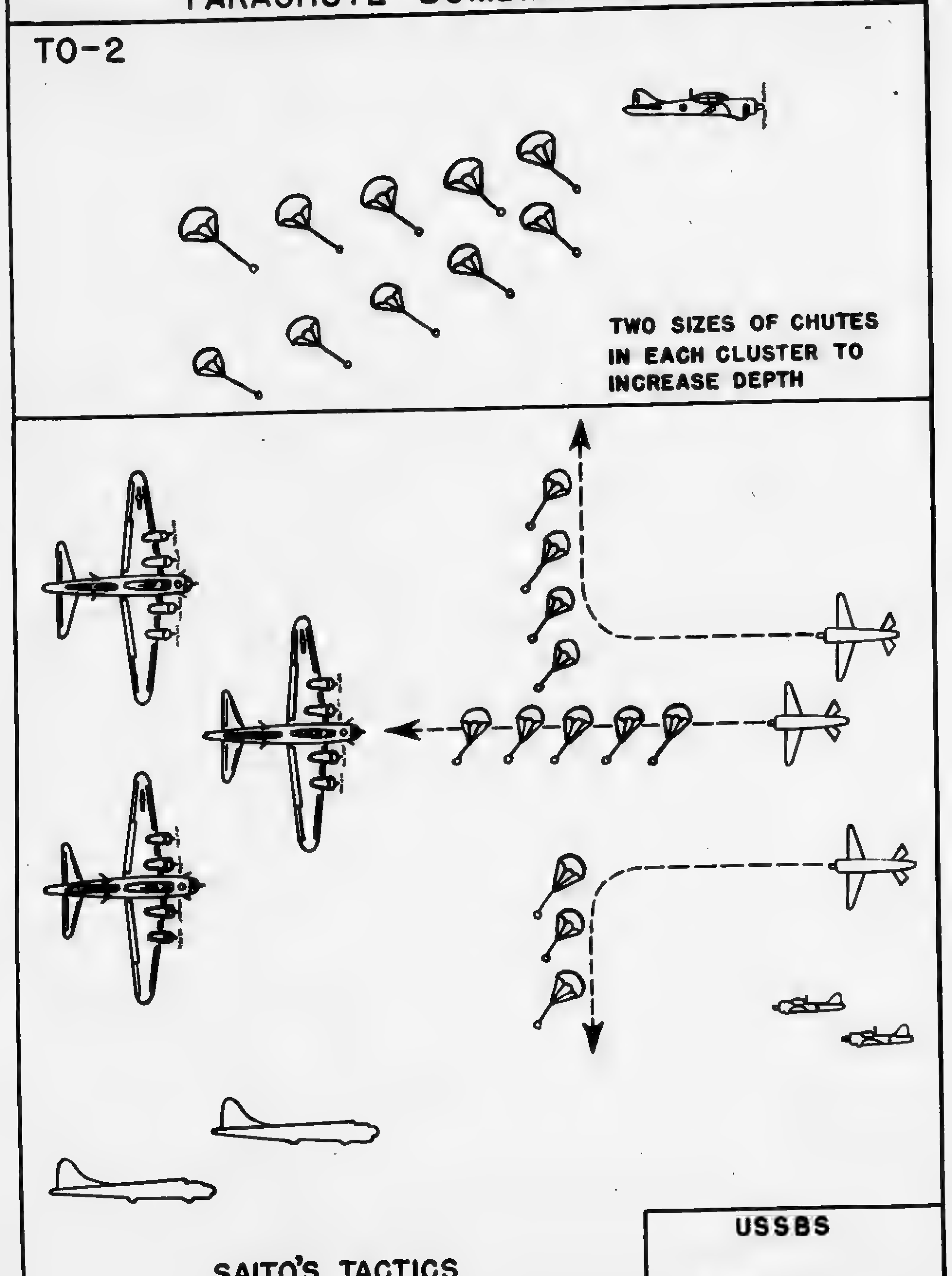


FIGURE —Y

AIR-TO-AIR INCENDIARY BOMBING

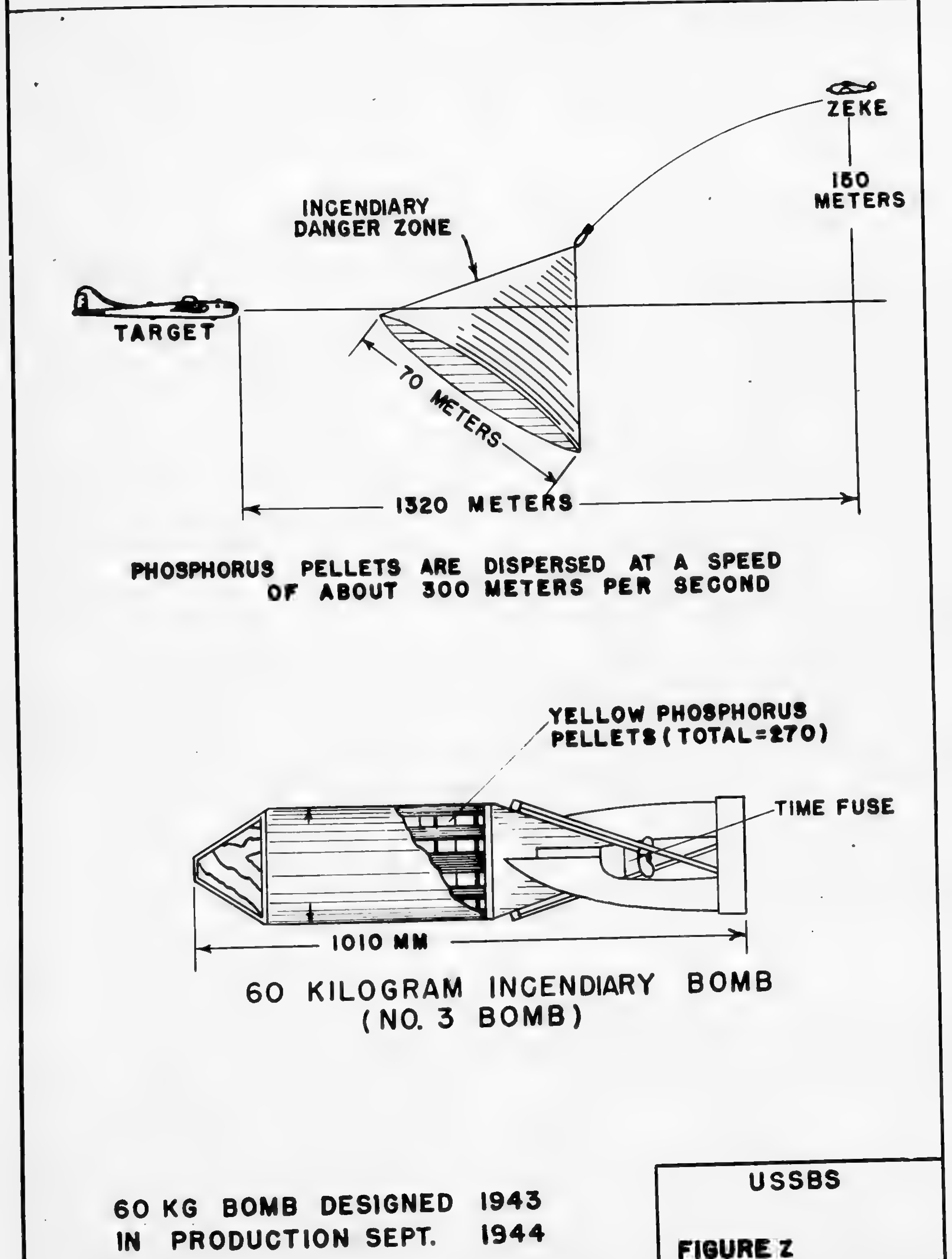
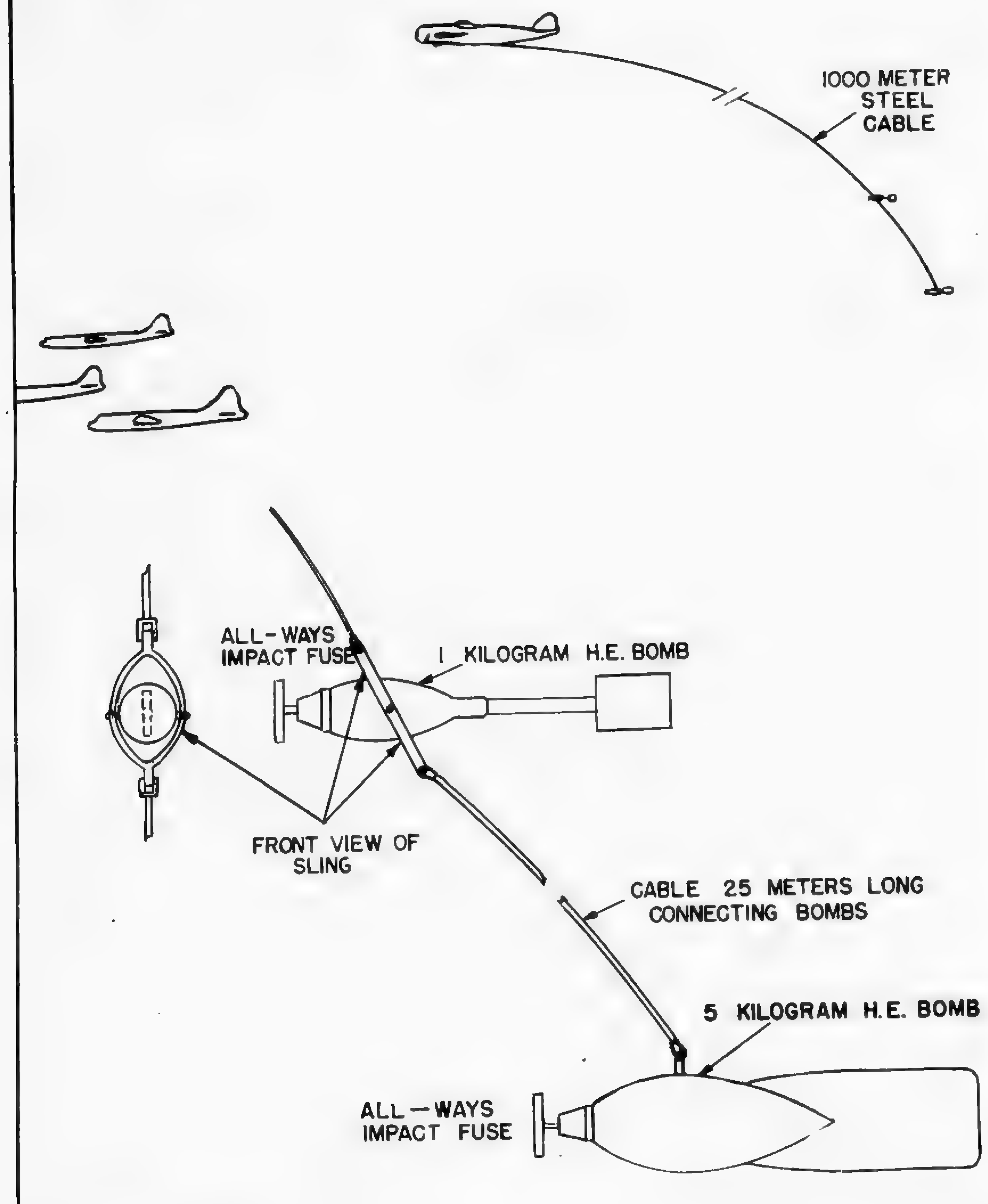


FIGURE Z



TO-1
CABLE BOMB

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FIGURE-AA

fighter upon approaching the bomber stream, and the attacker's altitude rendered him comparatively immune from the bomber defenses. However, instead of the German system of using standard heavy demolition bombs, the Japananese employed a pair of especially designed light-weight bombs incorporating a special release apparatus.

The Germans had early abandoned their cable-bombing tactics in view of the increased fighter vulnerability resulting from the very appreciable drag of the heavy demolition bomb. The more highly developed Japanese weapon sidestepped the heavy drag; but, nevertheless, did not become operational due to the high-altitude requirements exceeding the capabilities of the Jap aircraft.

The Japanese cable bombs were suspended in pairs, one bomb hanging 30 meters (98 feet) below the other. The heavier bomb hung at the cable's end, and the bomb weights were 1 kilogram (2.205 pounds) and 5 kilograms (11.025 pounds), respectively. The original purpose of the upper bomb was to cause the bomb load to hang lower and to overcome the tendency to drag directly behind the fighter (the initial prototype of the upper bomb was a 20-centimeter-span inert airfoil for this purpose). The airfoil finally evolved into the shape illustrated and included an explosive charge.

The German heavy demo-type cable bomb was more destructive, as 100 (220.5) to 200 kilograms (441 pounds) of explosive would cause damage within 50 meters (164 feet). However, this demolition advantage was more than overcome by the excessive drag, and was unessential to bomber destruction when incorporating an impact fuze. The Nipponese apparatus was more highly developed and its light bombs were easily capable of destroying a heavy bomber, but, as with most Japanese air-to-air techniques, the lack of a true high-altitude fighter precluded these potentially effective tactics. (German and Japanese cable bombs were apparently developed independently.)

"Scarecrow" Air Defenses

The attitude of passive bomber defense was further emphasized by the early adoption of defensive scare weapons, and reports indicate that these cheap makeshift missiles did have a deterrent effect upon Allied fighters. The following types were in operational use:

Defensive "Grenade" (Firecracker Type).—This was a waterproofed, pressed paper, spherical container 5½ inches in diameter. Inside was a black powder burster surrounding flash-producing pellets. Thrown by hand from the tail of the bomber, the container burst by a friction igniter and the pellets scattered producing flashy low-order explosions.

Defensive parachute "bomb" (nonexplosive.—These were small paper parachutes stabilized by inert weights and released by hand from the tail of the aircraft in clusters of 10. Usually about 50 of these small chutes were discharged simultaneously, and the fundamental psychological effect was further enhanced in view of the resemblance to the explosive To-2 parachute bombs.

The Ko-Dan (Rubber Bomb)

Theory.—Much experimental work was put into the "Ko" bomb, a novel rubber-cased demolition bomb believed to have extraordinary destructive power. The theoretical basis of the Ko bomb was "Kobayashi's Principle," which follows:

The energy of an explosion is projected along lines perpendicular to the surface of the explosive.

The amount of energy developed is proportional to the quantity of explosive within the neutral lines adjacent to the surface.

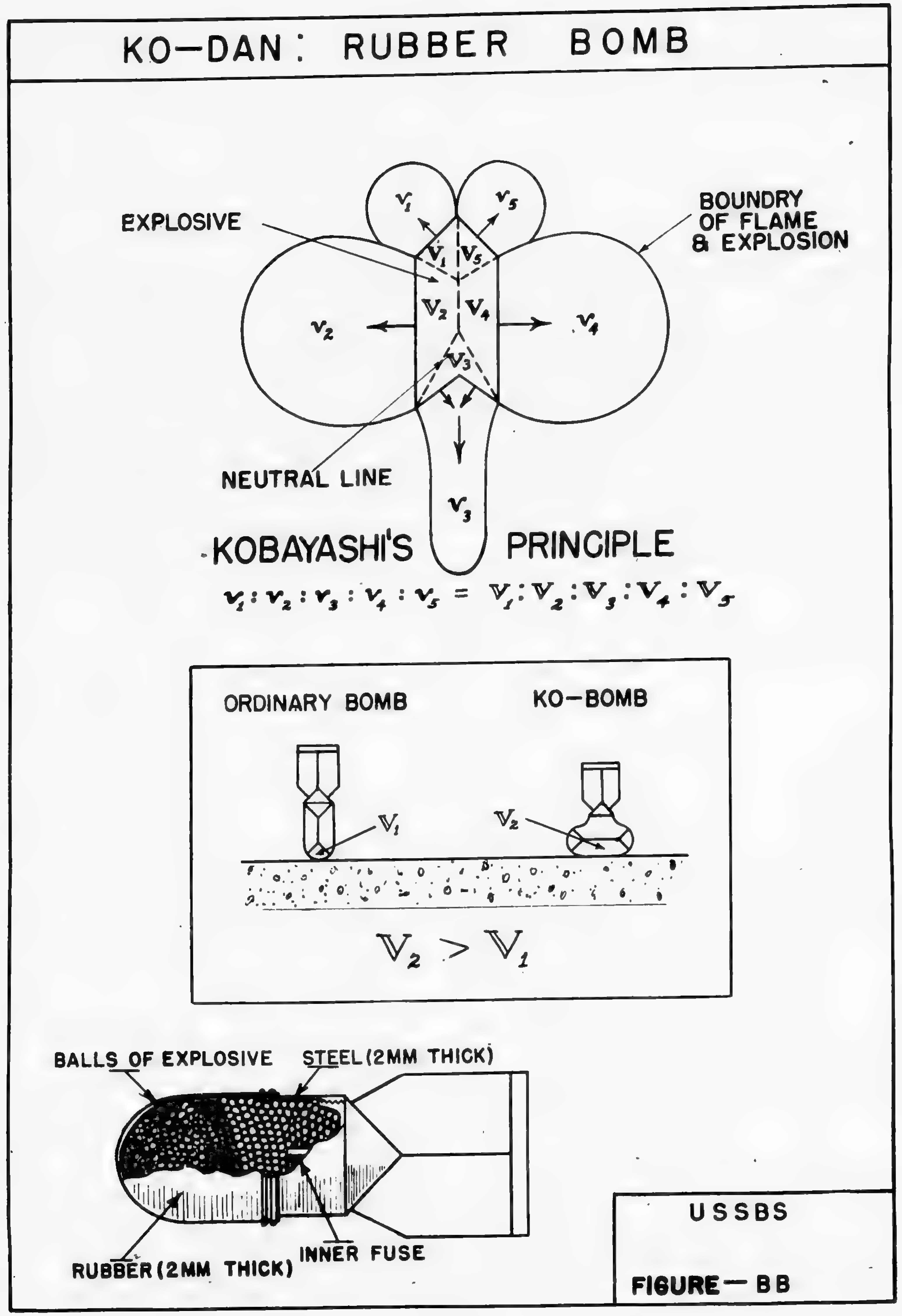
Kobayashi based his principle upon observations of ultra-high speed photographs of various shaped explosive charges in process of detonation (Figure BB).

Trials.—In the application of this theory it is readily seen that for maximum explosive effect we must increase the explosive's area of contact.

The Ko bomb was constructed with a rubber nose connected to a thin, 2-millimeter steel case. Upon impact the rubber nose was flattened, thus producing the larger desired contact area. The Ko was originally designed for employment against heavy concrete emplacements. According to General Masaki, an 85-kilogram bomb (187 pounds) (explosive charge=50 kilograms (110 pounds) of 50/50 ultropine and TNT) was capable of penetrating a reinforced concrete slab 1 meter thick with a resultant 1 meter (3,281 feet) diameter hole; a feat which would ordinarily require a 250-kilogram (551 pounds) ordinary demolition bomb.

Photoelectric Influence Fuze

General.—This Japanese fuze (type 3) was used operationally on 250- and 800-kilogram (551 and 1,764 pounds) aircraft bombs to cause detona-



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FIGURE—BB

tion 18 to 45 feet above the earth. The fuze functions in daylight or darkness.

Operation depends on transmitting from the fuze a beam of pulsing light which is reflected back to the fuze and activates a photoelectric cell, which, in connection with an electric circuit, causes detonation at a desired height.

Although limited operationally to use against ground targets, this principle promises an excellent solution to the free air-to-air bombing time-fuze problem.

Development and Manufacture.—The principle of the fuze is not new, but the reduction of the idea to a practical and reliable mechanism represents an appreciable achievement which required, among other things, the development and manufacture of a new photocell and thyratron tube. An earnest development program was initiated in November of 1943 at the first naval technical arsenal, Kanayawa, and only 9 months later, in July 1944, the fuze was used operationally. The number of fuzes manufactured was said to have been probably less than 1,500.

The main difficulties to be overcome were as follows:

The manufacture of a photocell which did not show "peaks," i. e., a photocell whose current output reliably followed a smooth curve as the light intensity increased.

The manufacture of a thyratron tube which was capable of withstanding the vibration encountered.

Principle of Operation.—As indicated in the diagram (Figure CC), the time of arming of the fuze may be set before the take-off at any value between 0 and 30 seconds. After arming, the point of detonation is determined principally by how good the target is as a light reflector.

A pulsing light source of 900 to 1,000 cycles per second is located in the fuze, and light from this source is directed toward the earth during the falling of the bomb. The pulsing light from the bomb strikes the target and is reflected back to a photoelectric cell in the fuze. The current from the photocell is amplified by an electronic circuit, tuned to 900–1,000 cycles per second, and connected to a thyratron tube. As the bomb nears the earth, the photoelectric cell receives more and more reflected light so that its current, which is amplified, increases until it triggers the thyratron. When the thyratron triggers, enough current passes through to the detonator to explode the bomb.

Since the amplifying circuit is sensitive only to light, pulsing at 900–1,000 cycles per second, a non-pulsing light will not activate the fuze and it may be used in daylight or darkness.

The type 3 photoelectric influence fuze is about 13 inches high and 10 inches in diameter.

Countermeasures.—At first thought it might be suggested that a searchlight pulsed at the proper frequency would cause the detonation of this fuze, but it must be realized that the fuze remains insensitive to such light until the arming switch is closed. If the dropping height is known sufficiently accurately when the arming-timer is being set, the period during which the bomb is capable of being activated by a pulse searchlight may be minimized so as to make searchlight detonation impracticable.

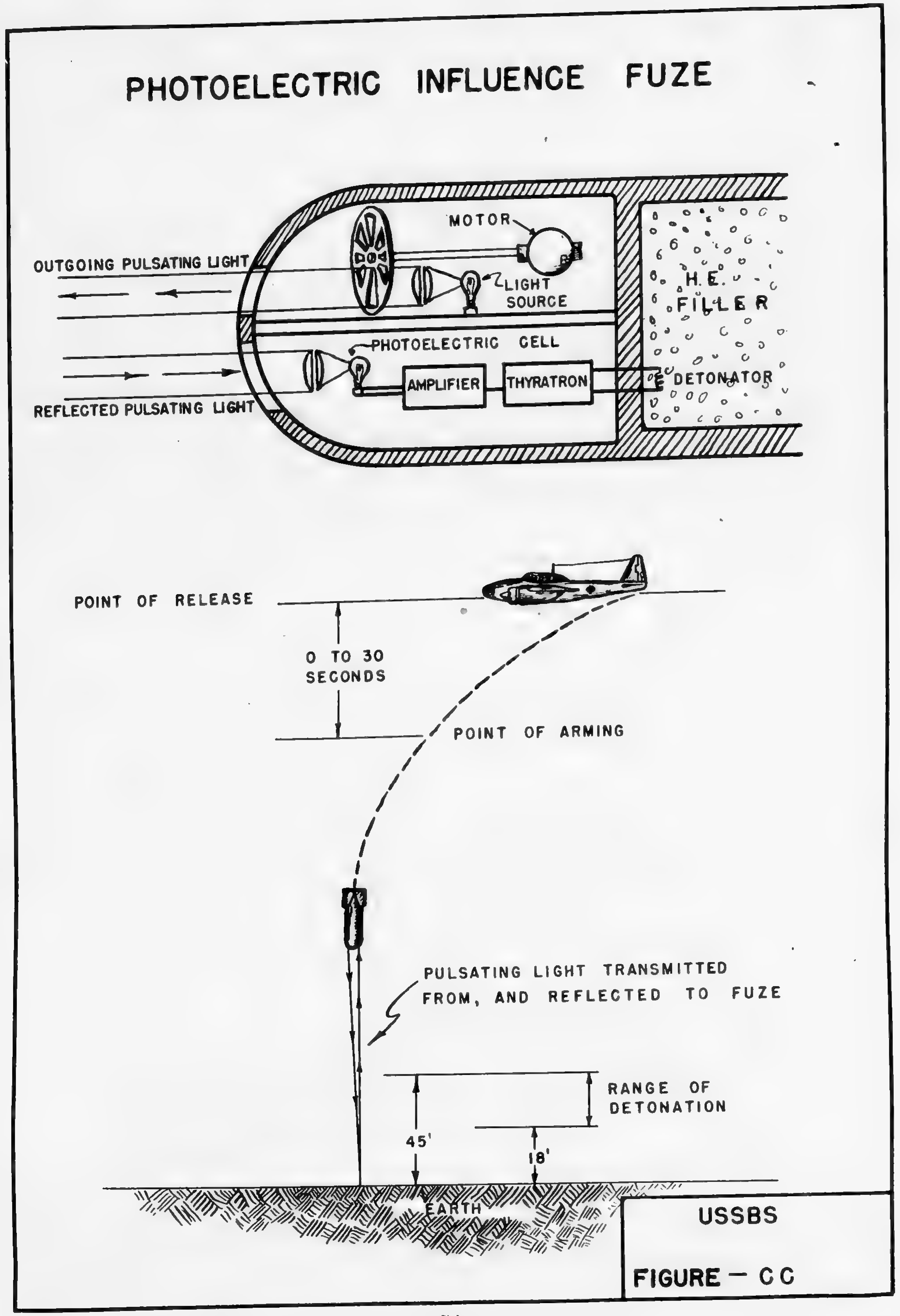


FIGURE — CC

XII. TORPEDOES

General

The Nipponese considered that the torpedo was the most lethal weapon in use against ships, and for the past 20 years the Japanese Navy has conducted an extensive research program. The result has been the design of torpedoes unrivalled in speed and range, yet carrying an extra weight of explosive. The Jap type 97 18-inch midget submarine (oxygen enriched) torpedo carries a larger explosive charge than United States, British, or German submarine torpedoes, yet weighs a great deal less, and its speed and range do not compare too unfavorably with those of the large 21-inch steam torpedoes.

Standard Aircraft Torpedoes

The operational aircraft torpedoes type 91, modifications 1, 2, and 3 have a common diameter of 18 inches, with an eight-cylinder steam engine. The engine is very well designed and built. It is probably original, and is readily adaptable to large-scale mass production. The disadvantage of the type 91 is its length, which because of its fragility necessitated a somewhat low dropping height on the part of Japanese torpedo planes.

Type 91, mod. II.—First manufactured in November 1931. Diameter, 45 centimeters (17.7 inches); velocity, 42 knots (48.3 miles per hour); length, 5,270 millimeters (17.3 feet); range, 2,000 meters (2,187 yards); explosive charge 150 kilograms (331 pounds).

This torpedo was used in the Malayan campaign in December 1941; and in the Coral Sea action in May 1942.

Type 91, mod. II.—First manufactured in April 1941. In this model the explosive charge was increased to 205 kilograms (452 pounds).

This torpedo was used at Pearl Harbor and Malaya in December 1941; Coral Sea in May 1942; Midway in June 1942; and in the South Pacific Ocean in August 1942.

Type 91, mod. III.—First manufactured in August 1941. In addition to an explosive charge increase to 240 kilograms (529 pounds); an eight-fin tail was fitted which gave improved aerial stabilization and excellent depth control. The eight fins appear to dampen out vibrations and were quite superior to the former four-fin type which gave relatively poor depth performance.

The warhead was interchangeable with the following alternate models:

Mod. III	240 kilograms, 529 pounds
Mod. IV	300 kilograms, 662 pounds
V-Head	305 kilograms, 673 pounds
Kite Head	335 kilograms, 739 pounds
Mod. VII	420 kilograms, 926 pounds

Type 4.—This new type was designed to simplify the mass-production and operation. It was built stronger to endure high-speed launching, and was put into mass production in December 1944, but never reached the operational stage. Speed, 42 knots (48 miles per hour); length, 5,270 millimeters (17.3 feet); range, 1,500 meters (1,641 yards).

Comparison of United States Navy and Japanese Aerial Torpedoes

The following chart compares the characteristics of the latest operational aircraft torpedoes. The principal United States Navy advantage of having 4,000 yards range was relatively unimportant, as the average horizontal range was closer to 1,000 yards and seldom exceeded 2,000. In the impor-

	Model	Over-all length	Diameter	Speed	Range	Total weight	Explosive weight
		Inches	*Inches*		*Yards*	*Pounds*	*Pounds*
United States Navy	Mark XIII Mod. III	161	22.4	38.6 miles per hour 33.5 knots	4,000	2,176	600
Imperial Japanese Navy	Type 91 Mod. VI	225	17.7	48.3 miles per hour 42 knots	3,100	2,100	[1] 821

[1] A Modification VII carries 924 pounds of explosive.

tant characteristics of speed and explosive weight the Japanese design was ahead. The potential launching speeds and altitudes of release were greater with the United States Navy torpedo; but the Japanese preference was for the greater hit probability offered by short ranges (which necessitated low speeds and low altitudes), with the safety factor given secondary consideration. (The slowest Japanese torpedo bomber, the type 96, Nell, is credited with the sinking of His Majesty's ship the *Prince of Wales* and His Majesty's ship *Repulse*).

It should be noted that in shallow water launching tactics (40-foot depth) speeds over 297 knots (342 miles per hour) and altitudes over 200 feet are likely to result in excessive bottom hitting.

Torpedo Bombers

Navy.—(In order of operational use):

a. *Type* 96 land attack plane (Nell).
b. Type 1 land attack plane (Betty).
c. "Ginka" land-based bomber (Frances).
d. Type 97 carrier-borne bomber (Kate).
e. "Tenzan" carrier-borne attack plane (Jill).
f. "Ryusei" carrier-borne attack plane (Grace).

It was hoped that Grace would be adopted as standard to fill all the requirements but considerable problems were met in the tail-control surfaces, although the wind tunnel models performed satisfactorily. Exhaustive checks eventually found the trouble in the Aichi company jigs; but in the interim many Grace were grounded while modifications were being made. Homare engine troubles also delayed the project. With the need for simplifying the whole aircraft production schedule, it was almost decided to concentrate on Myrt (reconnaissance) as the standard torpedo plane, discarding Grace and Jill for this work.

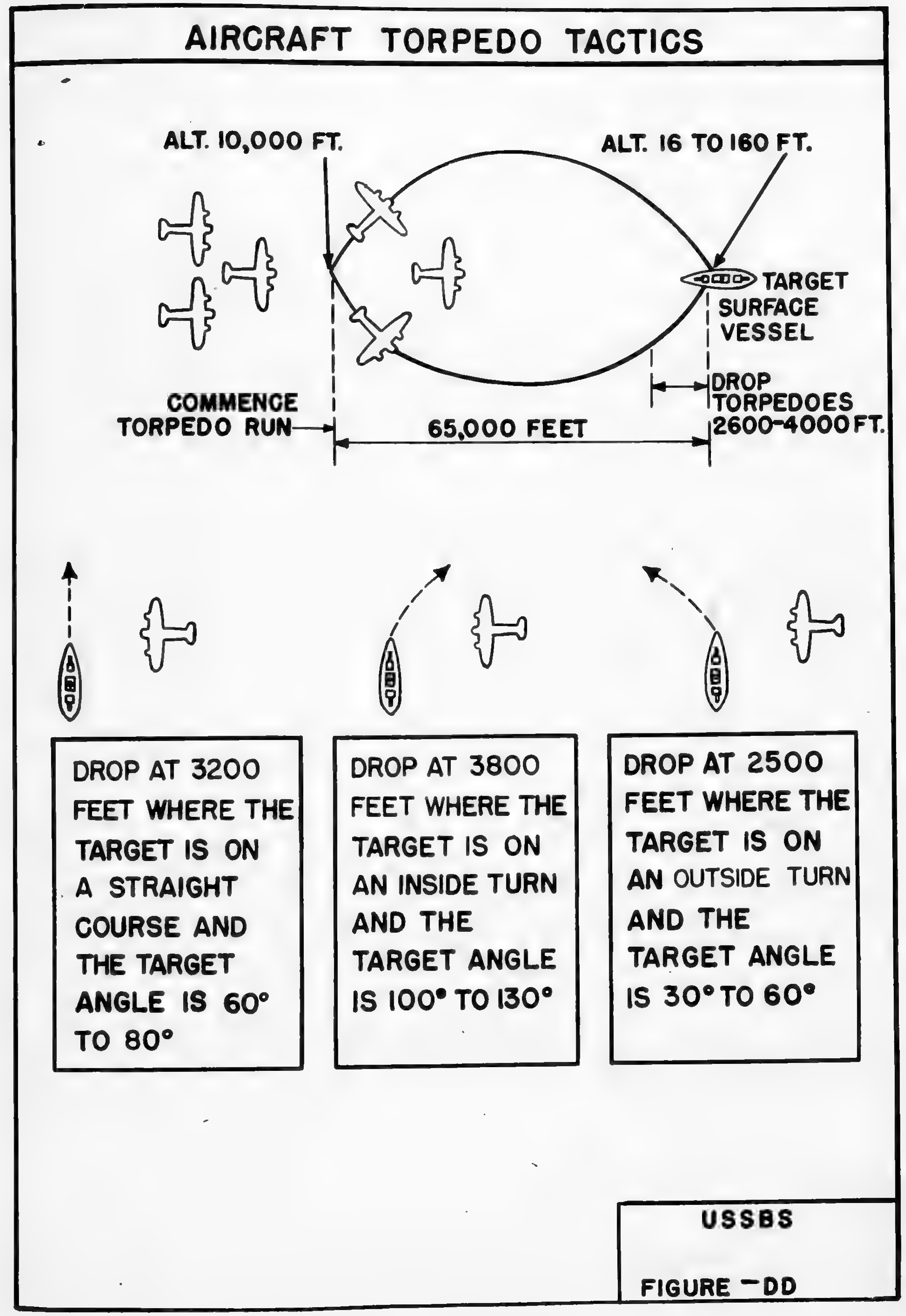
Army.—Since the Ki-67 bomber (Peggy) was very maneuverable and equipped with the necessary electrical apparatus and instruments for night flight, it was tested with torpedo equipment. The results showed satisfactory torpedo release up to the speed range of 550–600 kilometers per hour (342–373 miles per hour), so this launching apparatus was made standard on all these planes.

The first Army torpedo attack took place in the air battle off Taiwan in October 1944.

Torpedo Tactics (See Figure DD)

The standard approach for Japanese Navy torpedo planes was between 3,300 to 10,000 feet depending upon atmospheric and target conditions. When nearing the target ships, especially when within radar range, the planes dropped to 160 feet.

Unless in the face of heavy antiaircraft fire, the aircraft flew in a loose string and usually dropped the torpedo from the 160-foot altitude at an air speed of from 140 to 160 knots (161 to 184 miles). The release point was 2,600 to 4,000 feet in accordance with the final course of the target. (Later in the war, the potential launching speeds tended to increase along with increases in bomber speeds; and a late model Japanese torpedo permitted release at speeds up to 600 kilometers per hour (373 miles per hour).



XIII. AIR-LAUNCHED ROCKETS

Development

Although the Army and Navy had a rocket information exchange plan in effect since 1943, it was not until March 1944 that there began an attempt at "actual concrete cooperation." This belated effort was initiated with the decision for the Army to specialize in spin-stabilization and the Navy in the fin-type. (The primary reason for this "cooperation" was actually the persistence of each air force in adhering to their own beliefs.) The idea, and understanding was that should either air force perfect one of these types, they would both standardize on the perfected type.

The Navy's fin-stabilized rocket was the first to show success. The Army, however, protested that the Navy design was based upon the use of naval arsenal production equipment and that Army arsenals could not be readily adapted to such manufacture. Therefore, development of the Army's spin-stabilized rocket was continued, and eventually perfected and adopted by their own air force.

Operational Use

The Army had planned to employ rocket-carrying fighters to combat the Allied landing craft during the Okinawa campaign. However, at this time the spin-rockets were still not perfected, and at the war's end production had only just begun. Army ground force rockets were late in entering combat; being first encountered in the hills east of Manila. But the Army air force was still longer delayed; never reaching the operational stage.

XIV. GUIDED MISSILES AND PROXIMITY FUZES

General

Although none of the Japanese nonpiloted guided missiles reached the operational stage, the radio controlled I–GO bomb was close to perfection when the war ended. Two other interesting investigations had been undertaken: one regarding a heat-homing bomb; and the other a sound-controlled fuze.

The I–GO Bomb (Figure EE)

Following a conference on new weapons research, held 24 July 1944, it was decided to undertake the design of a radio controlled flying bomb. The I–GO was released from a parent plane at an altitude up to 1,500 meters (4922 feet) at a distance of 11 kilometers (6.84 miles) from its objective. It automatically descended to an altitude of 30–150 meters (98.4–492 feet), 5 kilometers (3.18 miles) from the target where a preset altimeter caused it to level off. After its release, I–GO was controlled by radio from a range increasing to 3 kilometers (1.86 miles) ahead of the mother plane until the time of impact.

No optical aid was afforded to the bombardier in controlling the flight of the 550-kilometer per hour (342 mile per hour) missile, nor was visibility assisted by any flame or smoke emission behind the bomb; however, a tail light was added for night employment to aid in keeping the bomb on course. The bombardier had full azimuth and altitude control over the missile, and he put it into a dive just before it got over the target.

Field tests.—The original plan called for two sizes of flying bombs designated the A and B models: the former was to be used against battleships and aircraft carriers; and the latter for employment against destroyers and cargo craft. By the end of October 1944, the first model B was completed by Kawasaki and tested in conjunction with the Ki–48. In the following month the I–GO A, constructed by Mitsubishi, was released from the Ki–67 mother plane. Totals of about 15 As and 150 Bs were produced and tested. It was finally decided to put all the effort on perfecting the I–GO A because of less electrical trouble and heavier warhead (800 kilograms (1764 pounds)). Both types showed their maximum error in range rather than in azimuth; striking from 30 meters (984 feet) short to 100 meters (328 feet) past the target, possibly due in great part to poor visual judgment.

The Heat-Homing Bomb (Figure FF)

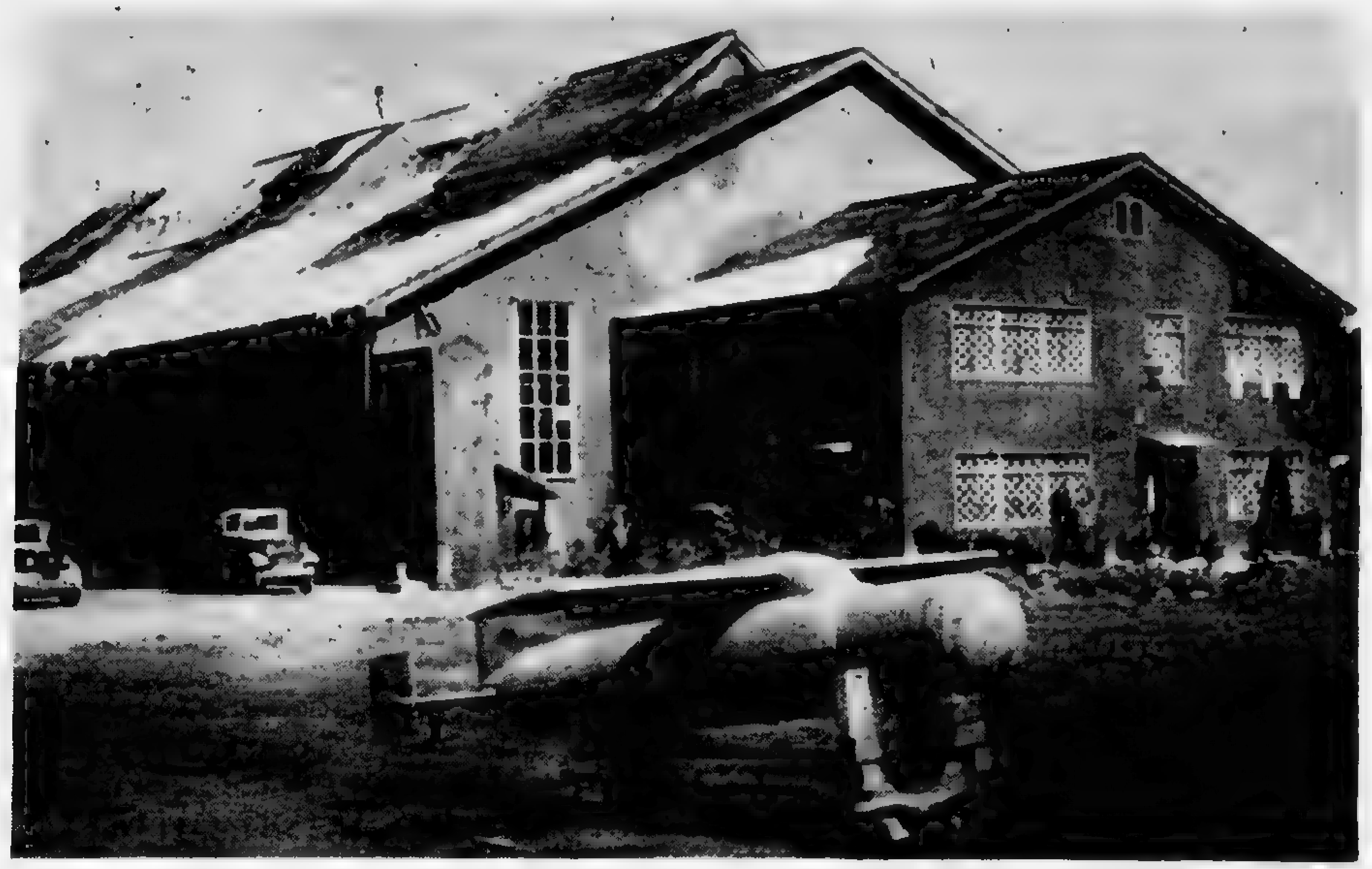
This type of bomb was planned for use solely against ships. They were to be employed at night because background conditions are more uniform for a heat-detector during that period. Nine different models were developed, but the first eight bombs were abandoned because of insufficient control. Mark IX, the latest, was designed with larger control surfaces, and it was expected that the final tests would be under way by the end of September 1945. It was stated that the Japanese obtained no outside aid in this development; information was unsuccessfully sought from Germany. Two other applications of the heat-detector had been considered: heat-homing boats and aircraft installations to locate enemy planes. However, by far the greatest portion of the work was done on the heat-homing bomb. (The heat-detector could detect a man's face at 100 meters (328 feet), and was therefore later given serious consideration for personnel detection.)

Field tests.—The only model extensively produced and tested was the Mark VII. Fifty or 60 were dropped from a plane at 3,000 meters (9,843 feet) altitude at a 10 x 20 meter (32.8 x 65.6 feet) raft target anchored near the center of Lake Hamanako (2,000 meters [6,562 feet] in radius). The heat was provided by burning four 4 x 4 meter (13 x 13 feet) wood and coal fires on the surface of the raft. Less than 10 percent of the bombs reacted to the controls.

The Mark IX bomb.—This final model was 5.45 meters (17.88 feet) long, 50 centimeters (19.7 inches) in diameter and weighed 800 kilograms (1.764 pounds) (explosive charge was 200 to 300 kilograms) (441 to 662 pounds). This model was provided with two sets of wings with aileron flaps controlled by an amplifier initiated by a bolometer

RADIO CONTROLLED BOMB I-GO

I-GO "A" BEING LOADED ON MOTHER PLANE



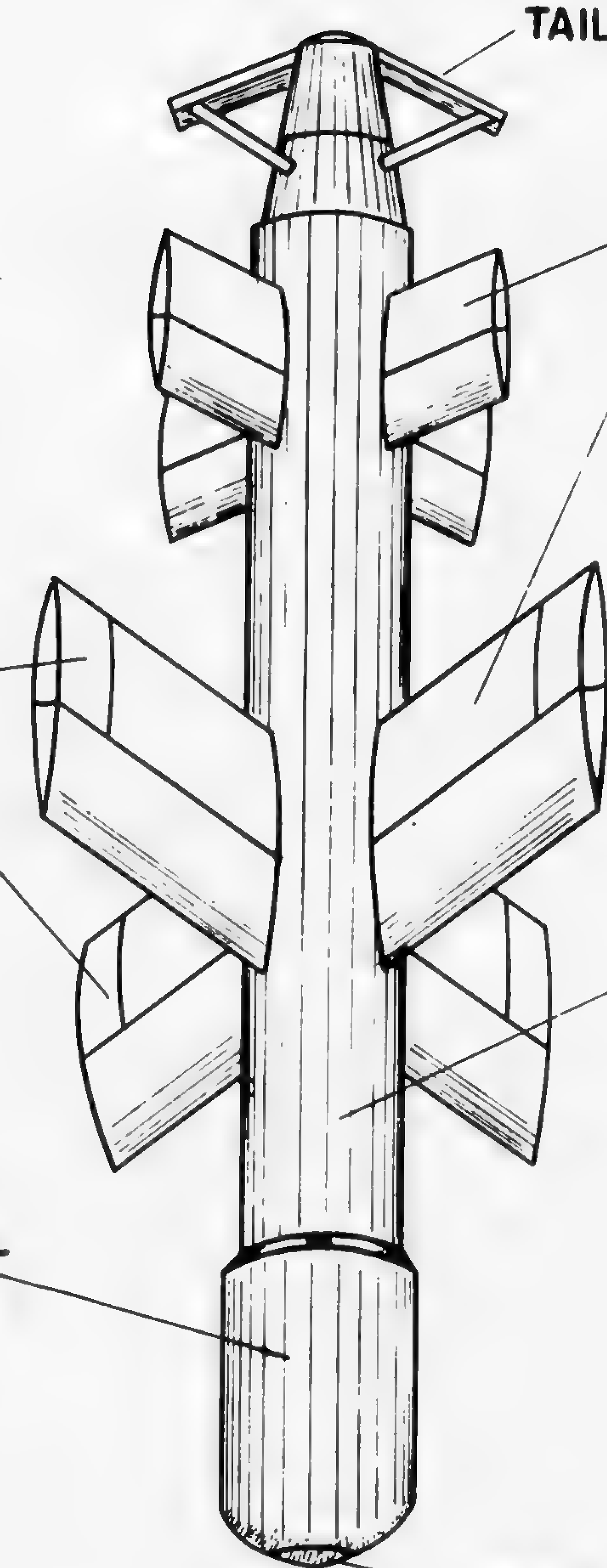
I-GO "B" ON CRADLE

TYPE	SPAN	TOTAL WT.	EXPLOSIVE	SPEED	RANGE	MOTHER
I-GO "A"	6 M	1500 KG.	800 KG.	550 KM/HR	11 KM	Ki -67
I-GO "B"	4 M	750 KG.	300 KG.	550 KM/HR	11 KM	Ki - 48

U.S. STRATEGIC BOMBING SURVEY

FIGURE EE

HEAT HOMING BOMB (MK IX)



MK IX	MODEL
LENGTH	5.4 METERS
DIAMETER	50 CENTIMETERS
TOTAL WT.	800 KILOGRAMS
EXPLOSIVE	300 KILOGRAMS

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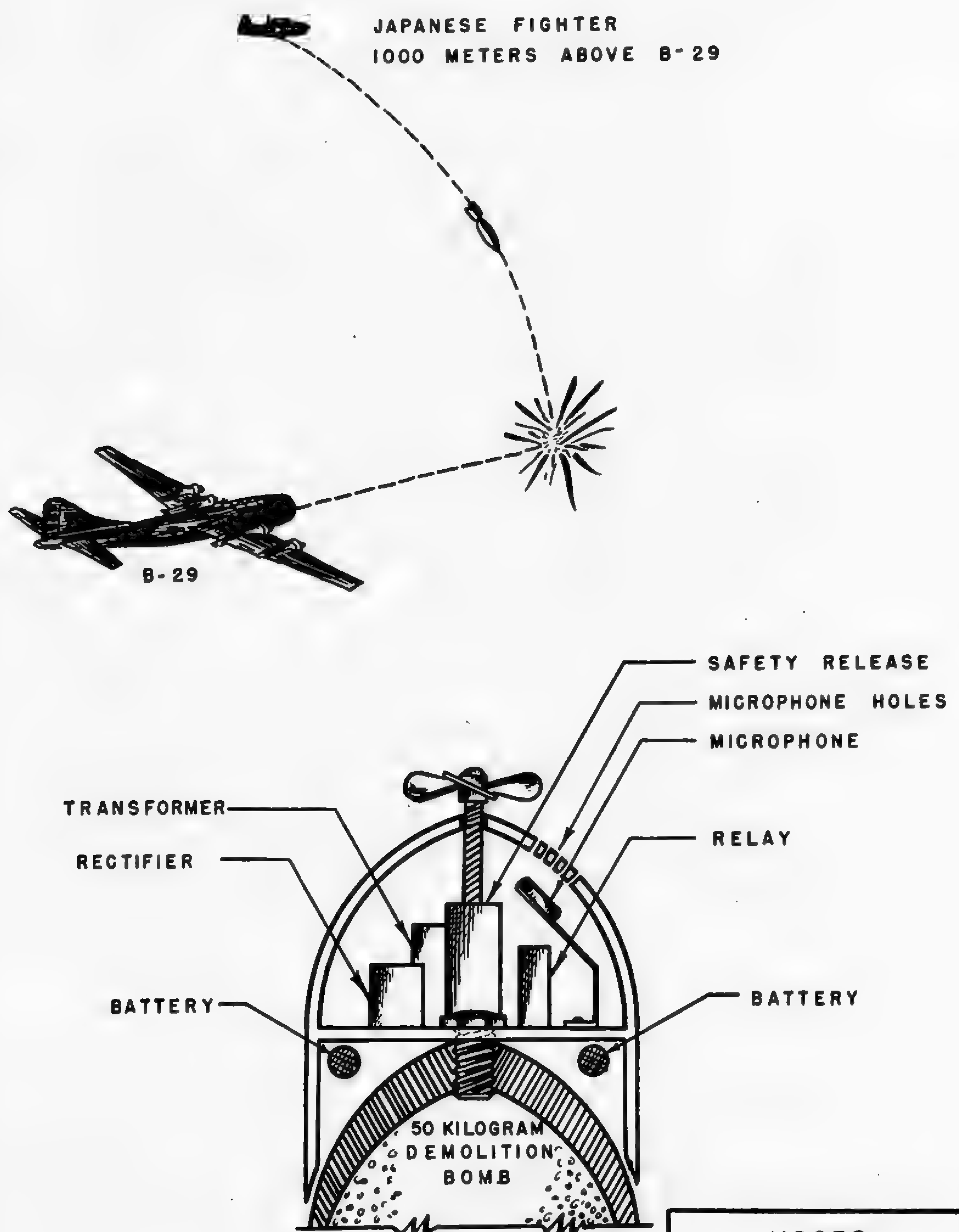
FIGURE - FF

SONIC-CONTROLLED BOMB FUZE



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FIGURE— G G

in the nose of the bomb. Stabilization was furnished by a gyroscope controlling four small flaps on the main wings. The speed was held back to 150 meters per second (492 feet per second) by a tail brake, in order to allow the controls time to operate. The controls were switched on automatically after descending to 2,000 meters (6,562 feet) altitude. From 2,000 meters (6,562 feet) full control will change the point of impact by 600 meters (1,968.6 feet) from the point of impact for free fall. A fuze was being designed to give an instantaneous burst with a direct hit on a ship, but providing a delay on a water hit to give maximum damaging effect.

The Acoustic Fuze (Figure GG)

This device was planned solely for use in an anti-B–29 weapon. This fuze, sensitive to the superforts' engine noise, was to be used in air-to-air bombing. In this manner Jap fighter-bombers could drop bombs into a B–29 formation without considering altitude or fuze-setting, and without necessitating direct hits.

Theoretical operation.—The arming vane is jettisoned almost immediately. Ten seconds later (to allow the missile to clear the mother plane) the switches are closed, and the reception of the B–29 noise causes a flow of current from the microphone. When the current reaches the desired flow, a relay is actuated, closing the switch of the fuze circuit and causing the bomb to explode.

Test and conclusions.—In laboratory bench tests, the sensitivity was of good order and the action fairly accurate. However, in actual drop tests it was found that the microphone responded only to the background noises caused by the tail fins, and was insensitive to the engine signal. In cases of finless bombs the background noises were negligible, but the resulting erratic path of the bomb rendered it useless for operations.

Modifications in the microphone size, size of the microphone holes, alteration of fins, etc., were under consideration, but the Japanese scarcity of true high-altitude fighters slowed up the interest in the weapon. Finally, when (after the fall of Iwo Jima and Okinawa) the American fighter escort tactics began, the Japanese gave up the idea of overhead air-to-air bombing, and this fuze was abandoned before the end of the war.

XV. AIRCRAFT ARMOR

Research and Development

The first investigations of the practicability of using armor in aircraft were begun during the Sino-Japanese war, but serious efforts were not applied until 1939 when the Russo-Japanese border warfare was under way. At this time some of the Russian planes were found to be using armor sheet. The requirements for armor installations did not become urgent, however, until after the outbreak of the war with the United States.

Early in the conflict the Japanese studied the armor installations on the B–17 and at that time launched systematic investigations. These experiments were planned to develop the following:

Special steels, especially ones using alloy substitutes for the critical nickel and molybdenum.

Superior heat treatments.

Composite armor sheet with double or triple layers arranged at various distances from each other (the optimum distance between two sheets of armor was stated to be two bullet lengths).

New and improved methods of surface hardening.

Armor sheet to defeat explosive shells.

Operational Use

In the early periods of the war, the Japanese used Ni-Cr-Mo, Mn-Cr-Mo, and Si-Mn-Cr steel for armor plate. Sheet thicknesses varied from two to 20 millimeters, but 8 millimeters, 12 millimeters, and 16 millimeters were finally adopted as standard. The 16 millimeter was most commonly used and would generally defeat all Allied armor-piercing and high-explosive projectiles.

The armor plate on a fighter weighed between 40 and 50 kilograms (88.2 and 110.25 pounds) and was generally installed behind the pilot. Bomber armor weighed up to 120 kilograms (264.6 pounds) and was generally distributed between the pilot, copilot, and gunner.

Despite these satisfactory developments, some aircraft types were still designed without either armor or bulletproof glass, and often with only one or the other. In many cases where armor was standard fighter equipment it was designed so as to be instantly detachable at the discretion of the pilot or organization, and this procedure was common practice due to the undesirable weight.

Comparison With United States Aircraft Armor

Chemical analysis:

(1) Homogeneous steel aircraft armor:

JAPANESE		UNITED STATES ARMY	
Carbon	.35–.45	Carbon	.35–.45
Silicon	.8–1.2	Chromium	1.10–1.30
Manganese	.8–1.2	Molybdenum	.50–.70
Chromium	.8–1.2	Vanadium	.15–.25

(2) Face-hardened steel aircraft armor:

JAPANESE	UNITED STATES ARMY	
Same as homogeneous, except for addition of carburized face. Surface hardening was incorporated in sheet thicknesses greater than 7 millimeters.	Carbon	.12–.18
	Nickel	3.30–3.60
	Molybdenum	.25–.35
	(.90 carbon in case.)	

Penetration Tests

A comparison of United States and Japanese resistivity tests for similar thicknesses of face-hardened plate reveals negligible differences. Japanese requirements were slightly higher against A. P. penetration and slightly lower against H. E. shock.

XVI. ELECTRONICS

Air-Borne Equipment

Designs of operational Japanese air-borne radar sets were somewhat similar to the early American SCR–521. There were sea search and patrol (ASV—air to surface vessel), altimeter, and a few IFF sets in use; but bombing through overcast (BTO) sets were still in the experimental stage when the war ended. A few aircraft interception (AI) sets had been produced but it appears that they were not employed operationally. It seems, however, that some of the search sets were used in a limited manner for torpedo attacks, bombing, and for tracking large aircraft.

The Navy began study on air-borne radar late in 1941. From this research was developed the H–6 patrol and search set operating at 150 megacycles. About 2,000 of these sets were produced by the Nihon Musen Co., and although they had limited accuracy their performance record was considered good. The lighter and more compact FK–3 was replacing the H–6 by the end of the war.

The Navy unsuccessfully tried adapting their 10-centimeter set No. 22 to air-borne use to obtain greater accuracy in azimuth and range. In 1944, the Germans sent the Japanese completed schematics of their Rotterdam Gerat. A few sets were manufactured from these specifications but the distance at which it could pick up the shore was only 20 kilometers (12.43 miles) which discouraged its large-scale production.

In 1943, the Army produced its first air-borne radar set. It was Taki 1, and was used in bombers for sea search. One Yagi antenna was mounted on the nose of the plane looking forward and a two x two array was used on either side. Each of these antennas was capable of transmitting and receiving. By means of an antenna switch, all three antennas could be used in rapid rotation, or singly to determine relative direction by the maximum indication method on an A-type presentation tube. Electronic range markers provided accurate target ranging.

Taki 1 gave satisfactory search performance but its 330 pounds was heavy for air-borne equipment. A second Taki 1 was designed weighing only 176 pounds but it was still in the laboratory stage when the war ended. Both models operated on a frequency of 150 megacycles and were rated at 10 kilowatts peak output power. Their range against ships was 62 miles and against submarines 12.5 miles with an accuracy of plus or minus 1.2 miles. Their azimuth accuracy was plus or minus 5°. A lighter model of Taki 1 had been developed for fighter bombers.

The Taki 2, which bears some resemblance to the German Lichtenstein (frequency and antenna) and the American SCR 540 (components) was being developed when the war ended. It was an 80-centimeter AI and ASV using Yagi arrays with folded dipoles. The transmitting antenna was installed on the nose of the plane with an antenna on each side of the nose for azimuth determination in addition to a vertically spaced pair for elevation. A motor-driven distributor connected each receiving antenna to the receiver in rapid succession. There were three cathode ray tube display systems, with one scope for the pilot and two for the observers use. Of the two scopes utilized by the observers, one provided range (A type) and the other indicated left-right and up-down signals. The remote cathode-ray tube used by the pilot duplicated this second presentation. A selsyn-controlled meter provided the pilot with the range of the target selected for viewing by the observer.

In late 1943, a 375-megacycle air-borne surface search set, called Taki 3, was developed by Tokyo Imperial University. Two Yagi antennas were placed side by side on the front of the plane to get direction. Fifty of these sets were produced but none ever were installed for operation because of its poor performance.

Early Warning Radar

The Japanese used a Doppler system of detection throughout the war in Japan and Korea. It was known as type A and employed a radio trans-

mitter operating on 40–80 megacycles which emitted continuous radio energy waves with superimposed audio modulation in as narrow a beam as convenient to a receiving station from 40 to 100 miles away. When an airplane crossed the beam, the tone heard at the receiving station was interrupted and a heavy beat note was picked up. The location of the body crossing the path of transmission was unknown; the only thing known was that there was an object within a range of 100 miles from the transmitter and somewhere within the directive beam. Although it had the advantage in getting range with little power, it could not get a definite location. The longest type A line of detection used was from Formosa to Shanghai, a distance of over 400 miles.

In 1940, a Japanese technical commission returned from Germany with tales of advanced electronic development; and experimentation was begun in that year on pulsed radar, known as type B. Captured sets and data from the Philippines and Malaya permitted the Japanese to produce type B units during 1942. The Army's Tachi 6, operating between 68–80 megacycles, proved too bulky for convenient use and two smaller more mobile sets were developed by June 1943. These were Tachi 7 and 18, both operating on 100 megacycles.

In 1942, the Army had built early warning radar sets designed for Army sea transport installation as they considered the Navy facilities unsatisfactory. After an unsuccessful attempt to set up their own sea air-warning system, the Army was forced to use these sets as fill-ins for their land based radar warning system.

The Navy's first type B set, radio detector No. 11 (Mark 1, model 1), also had been introduced in 1942 and also had been found too bulky. By the end of the year, a smaller No. 12 (Mark I, model II) had been built which was later adapted for ship-borne use. Nos. 13 and 13K were likewise designed to effect simpler and lighter sets for naval use. In 1942, 10-centimeter ship-borne search sets were installed with magnetrons used in both the transmitters and receivers. Wave guides were used to pipe energy to the horn antennas. The range of these sets was only about 15.5 miles.

Radio detector No. 14 (Mark I, model IV) operating at 50 megacycles was designed and produced late in the war to provide greater protection against increasing B–29 attacks. Several sets were installed in southern Kyushu in 1945 with a stated range of about 186 miles.

Ground Control Interception

The Japanese system of ground control interception was never satisfactory. A makeshift device was to employ two early warning sets, often Tachi 6 or 18, to track the enemy bombers and friendly interceptors respectively. There was no method of ascertaining the height of the enemy planes and the bearing and range errors were so large that a final separation of 10 kilometers (6.2 miles) between the planes was the best that could be obtained.

Two proposed solutions to the GCI problem were being studied when the war ended. One was to use the IFF interrogator Tachi 13, transmitting at 184 megacycles and receiving at 175 megacycles, along the plane's transpondor Taki 15 to both identify and fix the position of the night fighter. Another range finding radar would be employed to fix the position of the enemy plane at any moment.

The second system consisted of an automatic air-borne transmitter, ground direction-finding (D/F) receivers and VHF (very high frequency) radio links from the direction-finding installations to the control center. The air-borne transmitter transmitted on a frequency of 190 megacycles per second and was modulated by any one of 30 pre-selected "identification" frequencies between 30 and 60 kilocycles per second. The transmitted signals were received by the ground direction-finding receivers, provided with lobe-switched antennas for greater accuracy. The antennas were rotated continuously at a speed of 2 revolutions per minute. The received signals at the three direction-finding stations were related to the control center over a VHF radio link operating in the frequency band from 50 to 65 megacycles. The control center also was continously supplied with information on the bearing of the direction-finding antennas by the use of additional frequencies of 11, 13, and 15 kilocycles which modulated the very high frequency link.

At the control center, an azimuth "air-plot" picture was presented on a cathode ray tube, with an azimuth accuracy of one-half percent. Assignment of each of the 30 available "identification" frequencies to selected aircraft permitted the control center to track simultaneously a maximum of

30 planes by using the combined azimuth data from the three ground direction-finding receivers.

When the war ended, the Navy was developing radar sets for their new night fighters. FD–2 operating at 500 megacycles had a range of only 1.9 and 6.2 miles against other planes and ships respectively. It employed two sets of forward-looking Yagi antennas, one to transmit, the other to receive. Gyoku 3, operating at 150 megacycles had a range of 2.8 miles against medium type planes, but the set was never used operationally at night. It employed a specially constructed antenna which gave a forward looking conical scan. The antenna pattern was very broad, causing the image on the PPI (plan position indicator) tube to spread in azimuth with a resulting loss of definition.

Gun-Laying Radar

Japanese gun-laying radar first appeared in 1943 and was patterned after captured British SLC, GL Mark II, and the American SCR 268 sets. The complexity of the American unit made it difficult for the Japanese to copy, therefore their sets generally reflected the British influence. The first two Army sets, Tachi 1 and 2, had many features of the British SLC unit. Tachi 1 had separately mounted receiving and transmitting antennas and Tachi 2 had both antennas on the same reflector framework; both sets operated on 200 megacycles. A phasing ring was used on both to give the receiver lobe generated by the four Yagi receiving antennas a rotary movement. A mechanical distributor switched the received signal at appropriate moments to the azimuth or elevation scopes.

Tachi 4, which was developed to replace Tachi 1 and 2, was simplified by having transmitter and receiver mounted on the same carriage. This set was not very successful because it was inconvenient to handle and its accuracy was considered poor.

The Army favored Tachi 3 of their gunlaying radar sets, which was styled after the British GL Mark II and was operated at 78 megacycles. Its rated peak power output was 50 kilowatts. Pip-matching in both elevation and azimuth was accomplished by color disks. The Navy had built a unit called S–3 which was large and difficult to mass produce. It was replaced by the smaller, simpler, and more accurate S–24. The Navy admitted that the Army's Tachi 3 had greater range but compared it unfavorably to their own equipment as to azimuth and elevation.

A modified Tachi 4, in production at the end of the war, was designed to operate on 200 megacycles and was to use the same four Yagi antennas for transmitting and receiving in order to provide greater range and azimuth accuracy. The Army planned to adopt this set as their standard locator.

In early 1944, complete plans of the small 570-megacycle German Wurzburg were received by submarine. Three modified copies built by Nippon Musen which were to be used as models by Sumitomo and Shibaura had been produced but were not operational when the war ended.

XVII. THE PAPER BALLOONS

Development (Figure HH)

This type balloon was originally used by the Japanese for weather forecasting. With this purpose in mind, research was carried on as early as 1935, with paper balloons having a diameter of 4 meters (13.1 feet) and capable of ascending to 6 kilometers (3.73 miles). This objective having been attained, studies ceased in 1935.

When, on April 18, 1942, Japan was first bombed (Doolittle's raid) the effect on Japanese morale was such that all-out attempts were made to invoke retaliatory measures. Three methods of retaliation were under consideration by the Japanese General Staff: Balloons; aircraft; and submarines. With the desire to strike at the American homeland, the paper balloon studies were revived and accelerated. The initial plan (1942) was to develop balloons capable of traveling a distance of 3,000 kilometers (1,864.5 miles) and which would be released from combat surface vessels or from submarines off the coast of the United States. This objective necessitated increasing the balloon diameter from 4 to 6 meters (13.1 to 19.7 feet) and then to 8 meters (26.2 feet). Finally, in 1943 the balloon design was increased to 10 meters (32.8 feet) in diameter, and by that summer it was thought that the balloon could travel the required 3,000 kilometers (1,864.5 miles). However, the depleted Navy was so occupied by this time that ships were not available for carrying out the original plan of attack.

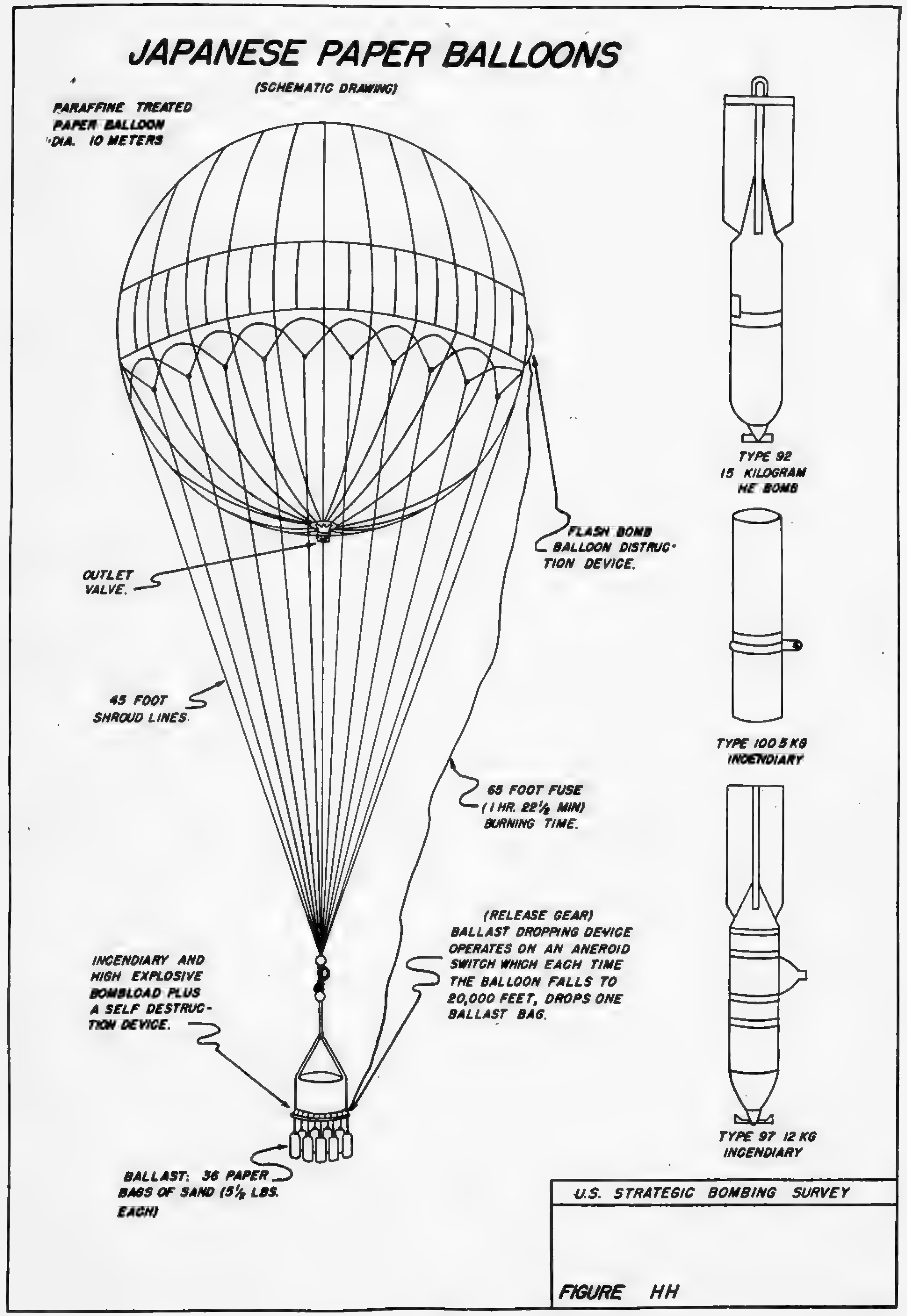
Trial Launchings

In view of the general situation, new investigations soon got under way to construct a balloon capable of traversing the entire distance between Japan and the United States. By 11 February 1944, 200 10-meter (32.8-foot) diameter balloons were available for trial. All 200 were released on this date as a test. Only a few carried incendiaries; the majority carried sand only. A two-station radio direction finder net, one station in Hokkaido and one in Chiba Prefecture, Honshu, was set up for the purpose of tracking the first part of the balloon's course. However, with this 250-mile base line, and an admitted error of plus or minus 2°, it was of course impossible to pin-point the location of balloons over 2,000 miles away; especially, in view of the fact that no meteorological data was available to the Japanese for the vast distances involved. A knowledge of weather would have assisted them in projecting the probable route. Aside from the immediate vicinity of Japan, accurate information was limited to the western coast of the United States. American broadcasts were closely followed since there were no facilities for observing results. On an assessment of information received from their communications authorities regarding unexpected fires in the United States, it was felt that some damage had been done.

Production and Mass Launchings

On the basis of these vague results, large-scale production of paper balloons began in April 1944. The cost of each balloon was first close to 10,000 yen but later was somewhat reduced as production increased. These balloons were hand made and were farmed out to small factories. The desired objective in production was 20,000 balloons, but only about 9,000 were ever finished. All the balloons constructed were released. A small number of rubberized-silk balloons carried a radio transmitter (1,000-mile range) and gave additional assistance in plotting the balloons' course.

Although the first specimens of the mass production were available in July and August, none was released until 20 November 1944. From then on, as many balloons as possible were sent in the direction of the United States, depending only upon production and existing meteorological conditions. The largest number of balloons ever sent in 1 month, 3,000, were released in March 1945, although climatic conditions were not most favorable during that month. On 13 March, 2 balloons were returned, after a 24-hour trip, to Japanese shores by freak winds. These were the only balloons to turn back and they did no damage since they fell in snowbanks. The last group of balloons was released 20 April 1945.



Bombload

The balloon payload was invariably two-thirds incendiary and one-third high explosive, and it was apparently never intended to alter these loads with chemical warfare materials or other weapons. The maximum bomb capacity estimated for each balloon by the Japanese was 30 kilograms (66 pounds); the average load was 24 kilograms (53 pounds), and the lightest was 12 kilograms (26.4 pounds).

Objectives and Results

The objective for this weapon was solely retaliation, and the Japanese did not expect it to be very effective. They stated that they would have been entirely satisfied if one-third of these balloons reached the United States. It is apparent that the ascent of the balloons was accompanied by much propaganda effort to uplift home front morale and to stimulate general production efforts. However, Japanese military officials stated that if the war continued, the materials used for the balloon production were to be given to other industries.

On 4 November 1944, a rubberized-silk balloon, supporting electronic devices, was retrieved from the ocean off the coast near San Pedro, Calif. Ten days later a paper balloon was picked up in the ocean near Hawaii. By 28 August 1945, a total of 296 confirmed balloon incidents were reported (including 3 of the rubberized type). These incidents ranged from Alaska to Mexico, and included the Aleutian Islands, 5 Canadian provinces, and 17 States in the western United States. Existing American radar equipment could not give satisfactory results in identification or detection of these balloons due to the weakness of the signal involved.

The American press furnished the Japanese with their best source of information by reporting the landing places of several balloons. This data touched off the Japanese propaganda program on 17 February 1945 when reference was made to the balloons in a Domei broadcast to the United States. The Japanese claimed that 500 casualties had been inflicted in the United States and numerous fires started. The broadcast also announced the United States authorities had found it necessary to issue general warnings against the attacks by the Japanese balloons and thus had aggravated unrest among the people. It was emphasized that these occurrences had shattered the American feeling of security against attacks by the Japanese. Subsequent Japanese broadcasts beamed to Europe, southeast Asia, and China repeated this theme, and in one instance, added that several million air-borne troops could be landed in the United States in the near future.

A broadcast in English from Singapore (Nampo-Domei) on 4 June 1945 predicted that when the "experimental" period is past, "large-scale attacks with death-defying Japanese airmen manning the balloons will be launched." A further inference of possible impending activity was made by the manager of the Domei news agency in Argentina who later stated that the balloons were a "prelude to something big."

It was realized in the United States that one evident purpose of the paper balloons was the transportation of incendiary and antipersonnel bombs. Military intelligence reactions pointed to the possible further utilization of the balloons as a prelude to the following activities, all of which were deemed practicable:

a. Biological warfare.

b. Transportation of agents.

c. Wind current data for long-range bomber attacks.

Conclusion

In view of the Japanese home front propaganda effect, and in consideration of the geographical location of the balloon landings, the paper balloon campaign was not an unsuccessful enterprise. In evaluating the 296 witnessed incidents, it must be realized that undoubtedly some balloons had arrived which were totally destroyed by the proper functioning of the incorporated destruction devices. The payload was principally incendiary, and a plotting of bomb incidents and balloon recoveries show that the great majority landed in the heavily forested areas of western United States, Canada, and Alaska.

XVIII. DEATH RAY

General

The Japanese worked on a "death ray" for 5½ years. The apparatus was based on the principle that very short radio waves focused in a beam of high power will cause physiological effects in mammals, resulting in death. The principal purpose of the research was to develop a military weapon which would cause paralysis or death to any human being upon whom the beam was focused. The primary application was expected to be as an antiaircraft device since the equipment was not easily portable. Throughout this program experiments were also tried on the effectiveness of short-wave radiation in stopping engines by causing preignition.

The research was thought promising enough to invest 2,000,000 yen on it, though it never reached the stage of practical application. Research was eventually placed in direct charge of General Kusaba whose section had earlier done the work on the paper balloons.

Research Programs

Effects against living things.

1940: Studies were initiated with the observation of injurious effects to mice and ground hogs in the field between condenser plates.

1941: A further study on the ellipsoidal focus was carried out.

1942: The causes and effects were studied physiologically and pathologically.

1943: Studies revealed that waves from 2 meters (78.74 inches) to 60 centimeters (22.62 inches) in length caused haemorrhage of lungs; waves shorter than 2 meters (78.74 inches) destroyed brain cells.

1944: More extensive studies were begun of the radiating electric field at a distance of 10 to 30 meters (32.8 to 98.4 feet) from the apparatus.

1945: Investigations ceased due to termination of the war.

Effects against engines.

1942: Studies were initiated with experiments on stopping automobile engines.

1943: It was found possible to stop engines (unless completely shielded) by tuned waves.

1944: Studies against aircraft engines were unsuccessful due to good shielding.

1945: Investigation began as to the effect of the wave in passing through the gap of the engine cover.

Experiments on Animals

The general nature of the apparatus was a high power short-wave oscillator feeding a dipole antenna which was placed at the focus of an ellipsoidal reflector. The animal was placed at the other focus of the ellipsoid. Experiments were conducted on mice, rabbits, ground hogs, and monkeys.

In 1944, with the 80 centimeter–30 kilowatt magnetron feeding a dipole in a 1-meter reflector, rabbits were killed in 10 minutes at a distance of 30 meters (98.4 feet); ground hogs took 20 minutes. No monkeys were utilized in these later experiments due to difficulties in obtaining specimens during the war.

The experiments planned in 1945 were to use four 300-kilowatt (input) magnetrons in parallel which were expected to give a total output of 250 to 300 kilowatts. These were to feed a dipole in a 10-meter (32.8 feet) diameter ellipsoidal reflector. It was calculated that this apparatus would kill a rabbit in 10 minutes at a distance of 1 kilometer (.62 mile). Wave lengths shorter than 80 centimeters (31.5 inches) appeared to be more effective, but research was concentrated on 80 centimeters (31.5 inches) because this was the shortest wave length at which the Japanese knew how to build output oscillators.

Future Potentialities

Allied research on radar has resulted in the development of higher power and shorter wavelength oscillators. If the Japanese experiments are reliable indications of the potentialities of the death ray, it is considered within the realm of possibility by eminent Allied scientists that a ray apparatus might be developed that could kill unshielded human beings at a distance of 5 to 10 miles.

UNITED STATES STRATEGIC BOMBING SURVEY

LIST OF REPORTS

The following is a bibliography of reports resulting from the Survey's studies of the European and Pacific wars. Certain of these reports may be purchased from the Superintendent of Documents at the Government Printing Office, Washington, D. C.

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11 Messerschmitt A G, Augsburg, Germany { Over-all Report; Part A; Part B; Appendices I, II, III
12 Dornier Works, Friedrichshafen & Munich, Germany
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17 Bavarian Motor Works Inc, Eisenach & Durrerhof, Germany
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52 Mayer and Schmidt, Offenbach on Main, Germany

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53 The German Anti-Friction Bearings Industry

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108 Gusstahlfabrik Friedrich Krupp, Essen, Germany

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U. S. GOVERNMENT PRINTING OFFICE: 1947